POLITECNICO DI MILANO
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MASTER THESIS

Tutor: Vincenzo Caglioti

LONG EXPOSURE VIDEO-SURVEILLANCE

ISOLATION OF NEW OBJECTS ON THE SCENARIO AND REJECTION OF DETECTION DUE TO MOVEMENT OF BACKGROUND OBJECTS

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1. INTRODUCTION

In this part of the project, a general point of view about the work developed is offered. Moreover, the objectives pursued are explained in detail. Besides, the tools used are listed and the document's structure is presented.

1.1 ABSTRACT

Video-surveillance is getting more and more importance nowadays. The main target is improving the level of understanding of the scene analyzed. However, when the level of scene detail is pushed into the background and the main objective of the system is **activity detection**, the low-level technique presented here could be, theoretically, more effective.

When using **long-exposure images** of the same scene, objects in motion appears **blurred** and **semi-transparent**, and these features increase with the time of exposure, until being totally invisible when using large times. As the main context where it is applied is Wireless Sensor Networks or similar, which require the minimal computing and communication features, using long-exposure images produces an **important decrease in the number of frames to send** to the surveillance-station, and linked to the technique's **low-computational effort** required, both facts enlarge the lifetime of the sensor batteries.

The basic method implemented in order to detect activity is differencing two consecutive images. The difference image represents the state of motion which has taken place during the lapse-time of both photographies, i.e., (theoretically), a black image if no activity is detected and, on the contrary, if an object has entered in the scene or a motion is produced on the scene the difference image pixels containing information about the motion will be represented in a colour, different from black. This is much easier of understanding if the difference image is later transformed into a "black and white image". Then, if no motion has been produced, a (theoretically) the difference image should be totally black, but if instead, a motion is produced the pixels affected by motion will be represented in white. Consequently, the device operates in two mainly modes

1)Idle Mode: It is expected that the great part of the time the device works in this mode, in which, it is waiting for any new activity on the scene.

2)Alert Mode: Once a presence is detected, the network is switched into this mode,and it should send an alert, and a new detection state, with more complex and specific detection and analyzing resources should be executed.

1.2. OBJECTIVES

Because of the Idle Mode dominance, luminance changes affect directly this mode. Luminance changes are an important factor when studying the image difference because they could lead into a false alarm when no activity is produced inside the scene during the lapse-time photographies. So that, reducing the impact of luminance changes

linked to the improvement of robustness of the differencing long-exposure images method has been one of the targets pursued in this project.

On the other hand, overall activity detection is not always convenient when talking in surveillance terms, because the main purpose may only be discerning **human activity detection.** As an example, an alert should not be sent if in an outdoor scene, a branch of a tree is moved by the wind. However, if a person has entered inside the scene this kind of motion must produce an alarm. So, this is another study matter in this work.

In order to study the different behaviours of this straightforward activity detection technique, its effects on different scenarios will be evaluated and compared.

Some techniques for eliminating the negative effect of eventual changes of luminance will be also researched.

Also it will be studied the effect of using different filters on the images that will be subtracted subsequently, constituting the difference image.

1.3. OPERATIONAL CONTEXT

1.3.1. Thesis Organization

This final thesis has been developed inside the Laboratorio di Robotica e Intelligenza Artificiale belonging to the Dipartamento di Elettronica e Informazione of the Facoltà di Ingegneria dell'Informazione del **Politenico di Milano** during the academic year 2009-2010 in the context of an Erasmus Program.

The tutor which guided the project is **Vincenzo Caglioti,** professor in the previous *Laboratorio di Robotica e Intelligenza Artificiale* at the Politecnico di Milano.

1.3.2. Tools

The program selected for evaluating the algorithms has been the proprietary software Matlab R2007a. Matlab is a numerical, technical computing environment offering own computing language and specific commands for Image analysis inside the *Image Processing Toolbox.*

The digital camera used for taking the long-exposure images is a NIKON-D40x. This is a reflex digital camera with 10,2 million pixels resolution and a 35-55photographic lens. Its minimum ISO is 100.

Figure 1. Camera used for taking long exposure images: Nikon D40x. (Images taken from www.nikon.com)

Besides, the use of a tripod has been compulsory in for not getting blurred images when using long-exposure times. An automatic trigger for the camera could be also very useful, although it has not been utilized in this project.

In order to avoid the over-exposure effect when using long exposures images in outdoor scenarios a glass of a sunglass is used as a neutral "filter".

1.4. STRUCTURE

This final thesis has been organized in 10 chapters.
In the first chapter, a presentation to the project and to the context where it has been developed is offered. Moreover, the objectives pursued during the project and the tools used for developing the implemented algorithms, and the material useful for taking the photographies is also commented.

In the second chapter, a deeper explanation of the basic method of Activity Detection by Differencing long-exposure images is presented.

In the third chapter, the different characteristics of the scenario selected and a list of the analyzed movements are presented.

In the fourth chapter, an explanation to the main steps and used techniques constituting each function used during the project is presented.

In the fifth chapter, the difference between the two filters most important for the project are described.

In the sixth chapter, the results obtained in the different scenarios are showed, although only for light clothes.

The seventh chapter talks about the main points observed during the project, meanwhile the eight chapter introduces other attempts tried which are not related with the isolation of movement from "new" objects on the scenario.

In chapter nine, the conclusions developed after the project performing are listed and in the last chapter some future works of research are presented.

2. ACTIVITY DETECTION.

2.1 EXPOSURE CONCEPT

In photography, the term exposure refers to the total amount of light allowed to fall on the photographic medium (photographic film or image sensor) during a single shutter speed. The resulting exposure number is computed from two different measures over a specific area: the exposure value (EV) and the scene luminance. In the exposure determination the level of sensitivity (ISO) of the photographic medium used is the main factor to have into account. Exposure is the result of the combination of the length of time ant the level of illumination which receives the photosensitive material. As can be seen, there is a direct relationship between luminance and exposure, and because of that, images taken in a luminous environment, e.g., outdoor scenarios with day-light (sunny day), will suffer over-exposure and will not be ever useful for the activity detection process. In a camera, exposure time depends on shutter speed, meanwhile luminance is controlled by lens aperture. In digital cameras, the sensitivity ISO can be varied within certain limits. A rule to be applied in order not to over-expose the image when taking long-exposure photographs of a (highly) lit scene is decreasing lens aperture and minimizing ISO.

2.2 LONG-EXPOSURE IMAGES APPLIED TO VIDEO-SURVEILLANCE

2.2.1 Blur in motion images

As previously commented, long exposure photography produce one or more blurred objects, when the object/s have been in movement during the time of exposure. This blurred appearance increases with the time of exposure and at a certain level the object/s in movement are completely invisible, as it will be shown later. Blur is a major problem when trying to analyze a scene in surveillance terms, because motion is more difficult to detect. Because of that, the time of exposure of the images that must be selected for acquiring good results in activity detection, must meet an equilibrium rule between being the largest as possible for decreasing the transmission frequency and robustness of detection capability.

2.2.2 Long-exposure images Differencing method

The technique consists in subtracting two consecutive images, thus, if some change has taken place during the instants in which the images were took, then they will appear in the resulting difference image. However, as change, it is not only referred to a change produced by the entrance of an intruder on the scenario, but only, luminance changes and other elements. Besides, sometimes the shadow of the intruder disturbs the detection technique. This is the reason why the identification of shadows is in several researches.

So, some factors may disturb the detection process and in other cases, the features of the intruder may not be recognized in the difference image.

3. SCENARIOS, MOTIONS & DETECTION FEATURES ANALYZED

3.1. SCENARIOS AND FEATURES

SCENARIO						
OUTDOOR 1						
	Outdoor1_morning	**Meteorological Conditions**	**Time**	**Outdoor 1_night**	**Meteorological Conditions**	**Time**
		Windy(light)	9:30		Windy(very)	22:00
	Shutter	**F**	**Filter**	**Shutter**	**F**	**Filter**
	1’’	10	-	1’’	3.5	-
	1.3’’	16	-	1.3’’	3.8	-
	1.6’’	18	-	1.6’’	3.8	-
	2’’	20	-	2’’	3.8	-
	2.5’’	22	-	2.5’’	3.8	-
	3’’	22	-	3’’	3.8	-
	4’’	16	YES	4’’	3.8	-
	5’’	18	YES	5’’	4.5	-
	6’’	18	YES	6’’	5	-
	8’’	20	YES	8’’	6.3	-
	10’’	22	YES	10’’	6.3	-
	15’’	22	YES	15’’	9	-
	20’’	22	YES	20’’	6.3	-
OUTDOOR 2						
	Outdoor2_morning	**Meteorological Conditions**	**Time**	**Outdoor 2_night**	**Meteorological Conditions**	**Time**
		Windy(very)(higher than the previous)	9:00		-	21:00 Twili-ght
	Shutter	**F**	**Filter**	**Shutter**	**F**	**Filter**
	1’’	20	-	1’’	3.5	-
	1.3’’	18	-	1.3’’	3.5	-
	1.6’’	16	YES	1.6’’	3.5	-
	2’’	11	YES	2’’	3.5	-

	2.5’’	13	YES	2.5’’	3.5	-
	3’’	14	YES	3’’	3.5	-
	4’’	14	YES	4’’	3.5	-
	5’’	16	YES	5’’	3.5	-
	6’’	18	YES	6’’	3.5	-
	8’’	20	YES	8’’	3.5	-
	10’’	22	YES	10’’	3.5	-
	15’’	22	YES	15’’	3.5	-
	20’’	22	YES	20’’	3.5	-

INDOOR 1

Shutter	F	Filter
1’’	4	-
1.3’’	4.5	-
1.6’’	5.6	-
2’’	6.3	-
2.5’’	6.3	-
3’’	8	-
4’’	8	-
5’’	9	-
6’’	10	-
8’’	11	-
10’’	13	-
15’’	16	-
20’’	18	-

INDOOR 2

Shutter	F	Filter
2’’		-

Lamp ON.
Large window and crystal door on the right. High luminance due to direct sun on this large window and door.

3.2 MOTION’S DIRECTIONS ANALYZED

The directions *ORTHOGONAL, PARALLEL or DIAGONAL* are referred to the camera’s axis.

SCENARIO	MOTION DIRECTION FOR LIGHT CLOTHES		MOTION DIRECTION FOR DARK CLOTHES (D)	
	ORTHOGONAL (B)	PARALLEL (C)	ORTHOGONAL (B)	PARALLEL (C)
OUTDOOR 1				

OUTDOOR 2	MOTION DIRECTION FOR LIGHT CLOTHES		MOTION DIRECTION FOR DARK CLOTHES (D)	
	ORTHOGONAL (B)	DIAGONAL (C)	ORTHOGONAL (B)	DIAGONAL (C)
				

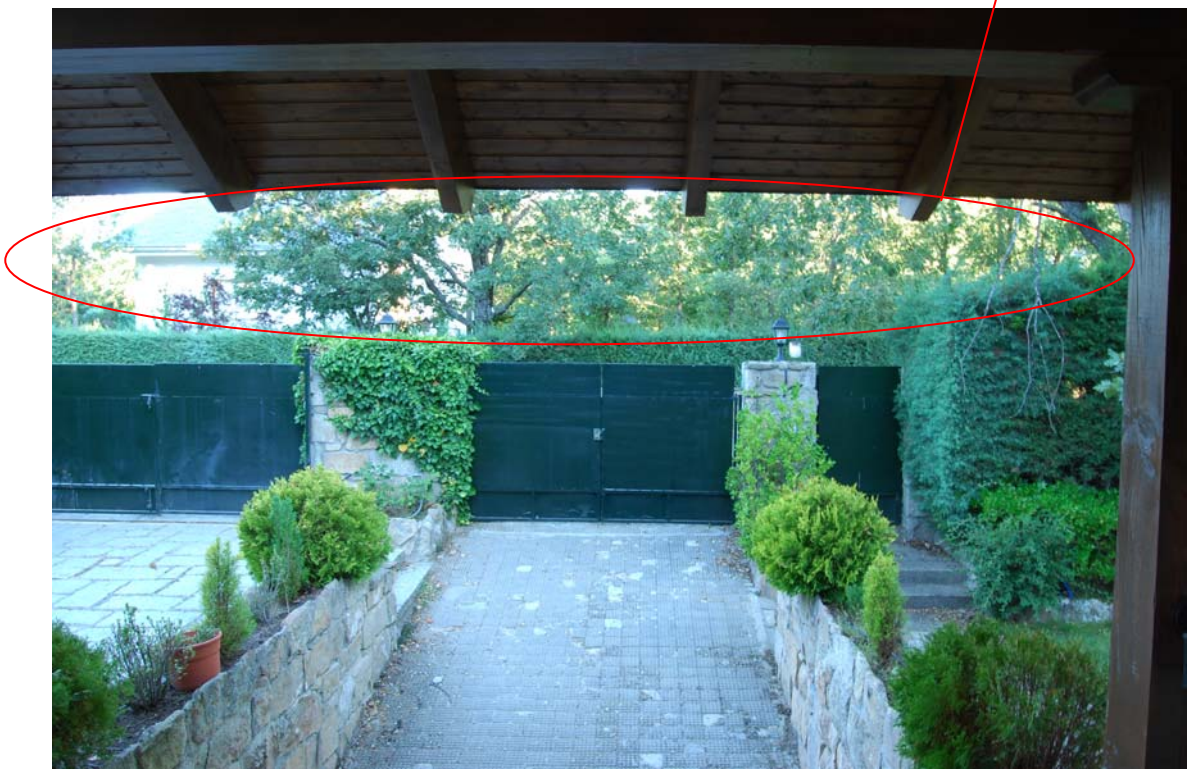
INDOOR 1	MOTION DIRECTION FOR LIGHT CLOTHES		MOTION DIRECTION FOR DARK CLOTHES (D)	
	ORTHOGONAL (B)	PARALLEL (C)	ORTHOGONAL (B)	PARALLEL (C)
				

INDOOR 2	MOTION DIRECTION	
	The man wears a white hat	
	ORTHOGONAL (B)	PARALLEL (C)
		

NOTE: The more useful scenarios for isolating activity referred to a object entering on the scenario and rejecting the activity proceeding from objects already present in the background (trees) , *(see 4.2.4.1.and 4.2.4.2.)*, are OUTDOOR 1 and OUTDOOR 3, because they include trees and plants whose movements should be rejected in the detection process meanwhile those from an intruder should be effectively detected.

The scenarios features in terms of the analysis conditions for the previous identification are showed here:

OUTDOOR1:



4. ISOLATING NEW OBJECTS MOTION, RELATED TO REJECTION OF MOVEMENT DETECTION OF OLD OBJECTS ON THE SCENARIO

4.1 INTRODUCTION

A general problem in this kind of surveillance is the accidental movement of objects which were already present on the scenario, and that will produce a false alarm, despite that any new object enters on the place being guarded. An example is the movements of plants due to draught caused by wind.

In this chapter, 4 methods are proposed in order to reduce the impact on the difference image which is due to this kind of motion components.

4.2 ALGORITHM EXPLANATION

4.2.1 Average image and Standard Deviation Image of a set of backgrounds

Every method computes the difference image, following the same steps. Firstly, a set of background images is introduced in the program and the average image is obtained by performing for each canal and for every pixel the mean of intensities inherent to each pixel through the set of images. This average image will be useful for computing the difference and it will be also used later in other process related with thresholding.

Similarly, the standard deviation image is calculated along the set of images. In this obtained image, for every canal, every pixel represents the root square of the variance along the set of images, i.e., the sum of the square of the difference between the intensity value of each pixel and its value in the average image. Then, for each canal a threshold corresponding to each canal is computed as the mean of the values taken by each pixel in the standard deviation image, obtaining 3 thresholds, one for each canal which will be used later in order to distinguishing the magnitude level of motions and also in the motion process distinction of “new”/ “old” objects on the guarded zone *(see 4.2.4.1.2).* This process has been selected from previous lectures that considered it the best method in order to increment the difference image quality and reject possible interferences.

4.2.2 Median/Hybrid Median Filter to the difference image

Once the average image is computed, a median/hybrid median filter is applied to it and also to the motion image in order to reduce their noise. Depending on the scenario, the size of the mask varies, but is always similar to the size of a person’s head on the scene. Another option is calculating the difference image and then filters it, but

this method has been rejected because maybe the noise included in both images affects negatively to the difference image.

4.2.3. Difference Image

Once filtered the images, the difference image can be obtained by applying the absolute value to the difference which results form subtracting the median filtered average image (of backgrounds) from the motion image(previously filtered).

It will be later explained, that sometimes, is better to perform the difference image only by subtracting both images, instead of computing subsequently the absolute value of this resulting image.

The reason of using the average image of a set of backgrounds in the computation of the difference, instead of the previous background image to the motion image, will be later explained.

4.2.4 Distinguishing of motion from “old” and “new” objects on the scenario

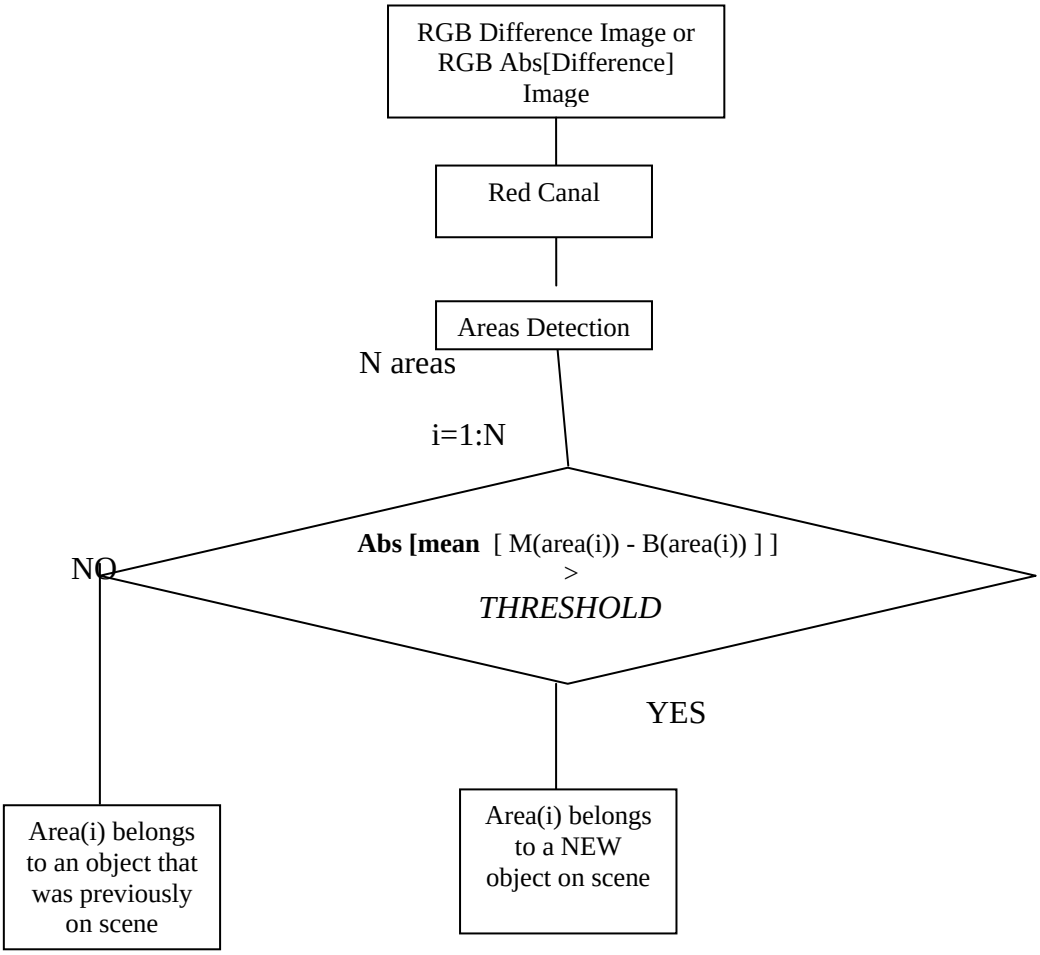
4.2.4.1 *Methods based on comparison of means of intensities in two consecutive images*

For distinguishing movements of “old” objects on the scene, such as a movement of a plant, from that coming from an intruder object, the first two methods are based on a comparison between the mean of intensities in the background (in our case the average image) and motion images, on each area of the difference image.

Theoretically, if no object has gone into the guarded zone during a set of consecutive frames, the mean of intensities of the image should remain constant despite of movement of objects that are part of it. But, if something enters into this zone, for example a person, the mean of intensities of the disturbed-background image analyzed will be considerably affected by the new object’s intensities.

So that, if no “new” objects affect the scenario, the difference between means of the intensities of two consecutive images should be zero.

However, what really happens is that there are always intensity changes between two consecutive images of the same scene, because of several factors, such as luminance changes, despite no “new” object intrusion on the scenario has taken place. So, in general, when considering two consecutive images, each particular area of their difference image is analyzed, and their regional means of their intensities in both images are computed. Later, the difference of both means is computed and the corresponding studied area will be only considered such as an area of “new” objects on the scene if this difference of means is greater than a certain value. On this aspect is where the first two methods based on the means, differs. Note that, while working with RGB images, the means comparison must be for each canal. Now, a diagram shows conceptually the processes followed in the two methods of means of intensities comparison, although it is only showed for the first canal, the red one. The same sequence must be implemented for the second and third canals.



In this diagram, B represents a background image and M represents the consecutive image to B.

4.2.4.1.1 Automatic regional threshold computation based on the mean of the regional standard deviation of intensities in the background image.

Firstly, it must be recalled that our background image is the average of a set of background images.
As explained previously, from two consecutive frames, F1 and F2, where F1 represents a background image (such as B in the last diagram), the difference image D is computed from as D=abs(F1-F2) (without considering the special that will be explained later, that does not take into account the absolute value). Later, for each canal, each area in D is studied and these values are computed:
- mean of their corresponding regional (*referred to each area*) intensities in the background frame F1
- standard deviation of the corresponding regional intensities in the background frame F1.
- mean of their corresponding regional intensities in the frame F2.

Subsequently, in the study of a particular area, the absolute value to the difference between the means previously computed, is taken. If this last value is greater than a function of the mean of the standard deviation of their regional intensities in F2, then the studied area is considered such as a “new object on scenario” area. If instead, it

is smaller than the standard deviation, the studied region corresponds to a movement of an object that was already present on the guarded zone.

This method has been called as ***Mean Correction1.***

4.2.4.1.2 Automatic regional threshold computation based on the mean of the standard deviations of intensities inherent to each pixel through a set of images. Application to regional means of intensities method.

In this second method, for each canal, the absolute value of the difference between the regional means of intensities of F1 and F2, is compared to the corresponding threshold obtained from the mean of the canal respective intensities in the standard deviation image, as explained in paragraph 4.2.1. If the absolute value is greater than this threshold value, the selected area belongs to a "new" object area. If not, the area corresponds to a movement of an "old" object.

This method has been called as ***Mean Correction2.***

4.2.4.2. Methods based on comparison of medians of intensities in two consecutive images

Similarly to the previous process related with motion distinction based on means, and having into account that the median is a better indicator of central tendency and a more robust method in presence of outlier values than the statistic mean, it was though to create an equivalent method based on median. So, theoretically, this method should be less influenced by eventual luminance changes, that wrongly increase pixels' intensity.

4.2.4.2.1. Automatic regional threshold computation based on the median of the regional standard deviation of intensities in the background image.

This process is analogous to the method explained on paragraph *4.2.4.1.1*, but instead of performing for each canal and for each are the means of the intensities in the corresponding area's pixels it performs the median. Besides, the comparison threshold is set as a function of the median of the standard deviation's intensities in the considered area.

This method has been called as ***Median Correction1.***

4.2.4.2.2. Automatic regional threshold computation based on the mean of the standard deviations of intensities inherent to each pixel through a set of images. Application to regional medians of intensities method.

In this fourth proposal, for each canal, the absolute value of the difference between the regional medians of intensities of F1 and F2, is compared to the corresponding threshold obtained from the mean of the canal respective intensities in the standard deviation image, as explained in paragraph 4.2.1. If the absolute value of the difference of the medians is greater than this threshold value, the selected area

belongs to an object that was not before in the background image, i.e. a new object. If not, the area corresponds to a movement of an "old" object.

This method has been called as ***Median Correction2.***

4.2.5. Opening of little areas

After the removal of areas that did not belong, theoretically, to a "new" object, an opening process is performed. The reason why this processing is used, is that, in video-surveillance, the main target is to recognize **human intruders.** So that, taking the hypothesis that a **person occupies the 25% of an image**, little objects detected, whose size is very small, compared to a person's size can be removed. Furthermore, in **long exposure video-surveillance** not only the silhouette of a person is detected, but a whole "trail" appears in the motion zone, so that, the opening process could be better justified in this kind of surveillance.

The *opening* of an image *A* by a structure *B,* consists of an erosion followed by a dilation of the image obtained by *B.* An easy geometric interpretation of this kind of transformation by an sphere, is showed below, where A(x,y) is supposed to be represented in three dimensions, where the gray level corresponds to the third coordinate. The opening of A by the sphere is represented by the displacement of the sphere, such as a *rolling ball,* under the surface limited by the gray level.

4.2.6. Distinction of the activity's magnitude

The areas detected in the *opened* image, suffer a classification based on a intensity comparison for each one of the pixels constituting the area, with several multiples of each one of the three threshold defined in 4.2.4.1.2, i.e., for each canal, each pixel of each area is compared with several multiples of the corresponding threshold for this anal. Thus, after this treatment, each pixel in the *opened* image will have an output intensity as high as the value defined for the range to which the input pixel belongs. Consequently, pixels corresponding to the most intense activity will have the highest level of intensity whereas pixels corresponding to a medium level of activity will have a lower value, and pixels representing areas where there was hardly any activity, won't be represented in the final image, achieving an image showing graduate levels of motion.

4.2.7. Edge Detection

In order to find the edges of the image obtained after the opening process, described in 4.2.5, the *Canny* edge detector is applied to this image. This kind of edge detector was selected because its performance is, generally, superior to other methods such as the *Sobel, Prewitt* or the *Roberts cross-gradient operators*. The *Canny* edge detector uses numerical optimization in order to meet three basic targets:
-low error rate,
-edge points should be well localized
-singel edge point response

4.2.8. Boundaries and Holes extraction

The boundary of an object *P* is obtained by performing an eroding process by an structuring element *B*, and then substracting the obtained result from the initial object *P*.

$$Boundary(P)=P-(A \ominus B)$$

In the next example, the process is illustrated:

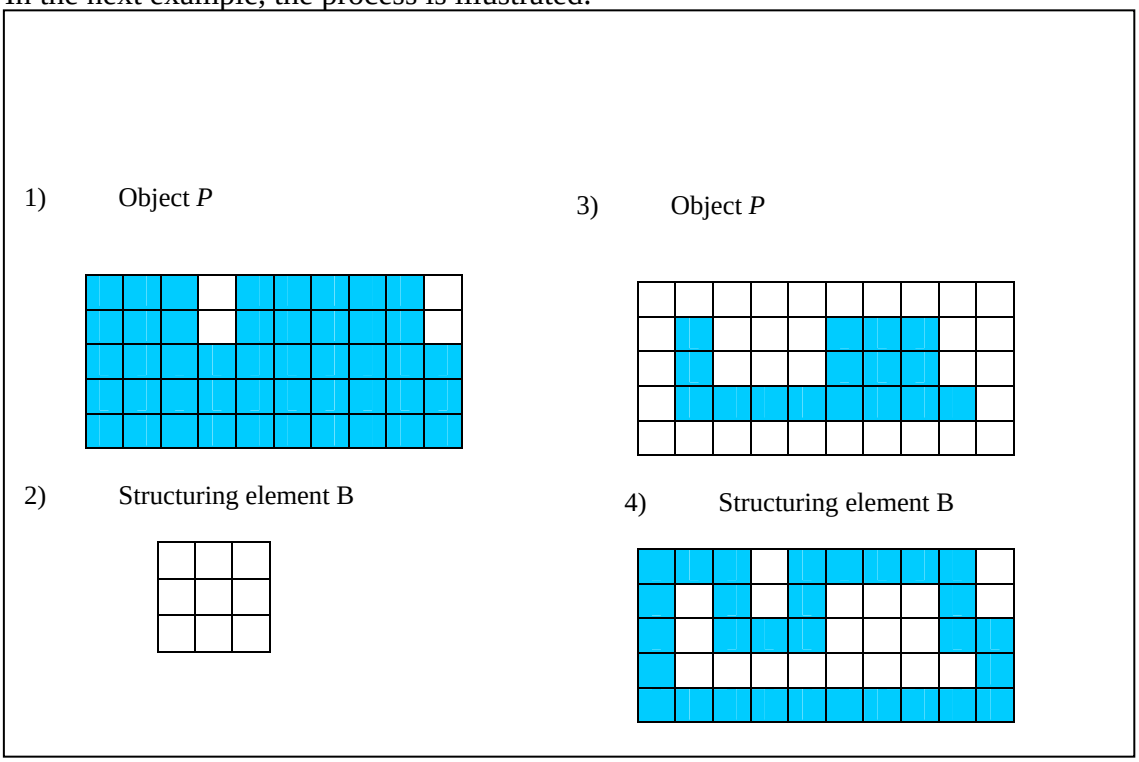


Figure : Boundary extraction process. Figure based on the *Figure 9.13.*

4.2.9. Deblurring

4.2.9.1. Introduction to Deblurring

In this kind of surveillance using long exposure images, when an intruder is detected, it does not appears as a well-defined silhouette, instead, as commented previously the region affected by the motion of the intruder appears semi-transparent and blurred. For this reason, an attempt to diminish the blur on the motion zone has been tried by testing several deconvolution methods.

The next deblurring processes included in *MATLAB* were tested:
-Deblurring with Wiener Filter
-Deblurring with a regularized filter
-Deblurring with the Blind Deconvolution
-Deblurring with the Lucy-Richardson Algorithm
Finally, the process which turned out to be more effective using this size of PSF was the *Lucy-Richardson Algorithm.*

4.2.9.2. Deconvolution by Lucy-Richardson Algorithm
This is an iterative non-linear restoring process where the image is modelled as an statistic Gaussian distribution and propose a maximum-likelihood method.

In maximum-likelihood restoration processes, noise amplification is a common problem, but the *MATLAB* function corresponding to this type of deblurring establishes a damping parameter in order not to increase this problem.

5.COMPARISON OF FILTERS FOR ACTIVITY DETECTION

5.1. INTRODUCTION

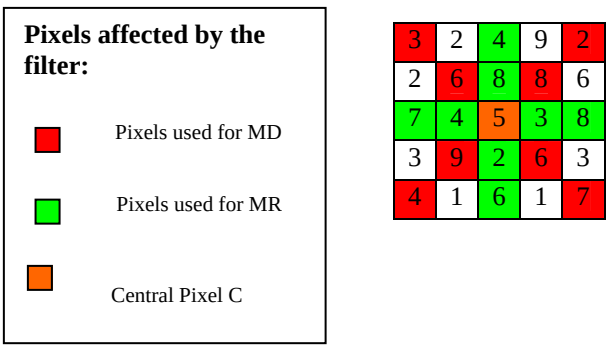
Reduction of certain types of random noise and removal of small details of the images, are important tasks in this kind of image processing. So that, smoothing spatial filters are suitable tools to perform these operations.
In this project, non-linear *median* and *hybrid median filters*, a special kind of median filter, are studied and their results are compared.

5.2. MEDIAN FILTER

The most common spatial filter used in this kind of image processing is the median filter, which replaces the value at which the filter is applied (central pixel), by the median of the intensities of his neighbours, (once defined an $m \times n$ neighbourhood). The original value of the pixel is included in the computation of the neighbourhood's median. The reason why these non-linear filters are so used is their great effectiveness in presence of certain kinds of random noise. Thus, noise is greatly decreased whereas provide a better edge preservation than linear smoothing filters, such as average or weighted average filters, of the same size.
As mentioned before, here, the size of the kernel used, depends on the scenario, but it is always similar to the size of a person in the guarded zone.

5.3. HYBRID MEDIAN FILTER

A special kind of median filter, *the hybrid median filter*, actuates separately on different directions of a square-kernel, thus, providing a better edge preservation, than the usual median filter using a kernel of similar size. In the *hybrid median filter implemented here*, **once** defined the $n \times n$ mask, three medians are calculated in the mask. Firstly, the median *MR* of the horizontal and vertical pixels in the mask is computed. Then, separately, a second median *MD* is calculated using the values on the diagonals in the $n \times n$ kernel, and finally, the value which will substitute the central pixel of the mask is computed as the median of the two medians previously defined and the original value of the central pixel. The way in which this filter works is explained on the 5x5 kernel showed below:



MD = median(3,2,6,8,9,6,4,7)
= 6

3	2	4	9	2
2	6	8	8	6
7	4	5	3	8
3	9	2	6	3
4	1	6	1	7

MR = median(4,8,7,4,3,8,2,6)
= 5

3	2	4	9	2
2	6	8	8	6
7	4	5	3	8
3	9	2	6	3
4	1	6	1	7

Hybrid median=median(MD,MR,C)=median(6,5,5)=5

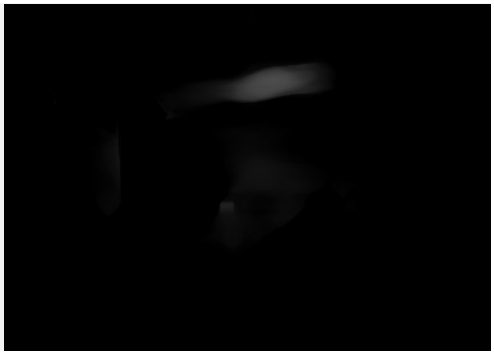
6. RESULTS

6.1. INTRODUCTION

In this section, the most important results will be displayed, whether they are effective or not. Prior to the list of results, the reason why the images were processed following some particular kinds of detection methods are presented.

6.2 SELECTION OF THE BEST METHOD FOR DISTINGUISHING ACTIVITY DETECTION FROM "OLD" AND "NEW" OBJECTS ON THE SCENARIO

The four methods listed at paragraph 4.2.4.1. were analyzed on several difference images proceeding from different scenarios and with diverse shutter speeds. However, all of them presented very similar results, although the most effective approach turned out to be that performing the regional comparison of medians of intensities and that also use a threshold based on the median of the regional standard deviations for each area, i.e., the approach belonging to the 4.2.4.1.1. paragraph. Some of the obtained results are presented here,:

Shutter	**Initial Motion Image**	
2''		
	Difference image (gray-scale)	**Canal 2 of the initial difference image**
		
	Mean-Correction1 to Canal 2	Mean-Correction2 to Canal2

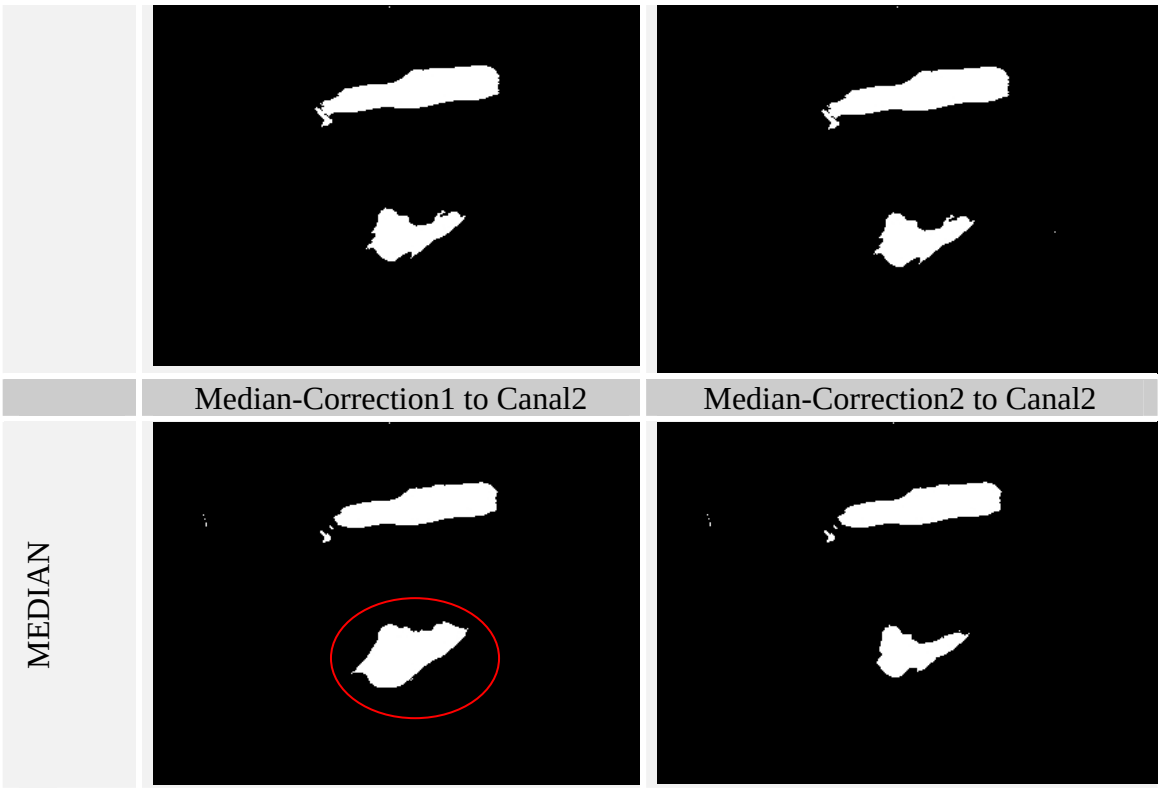
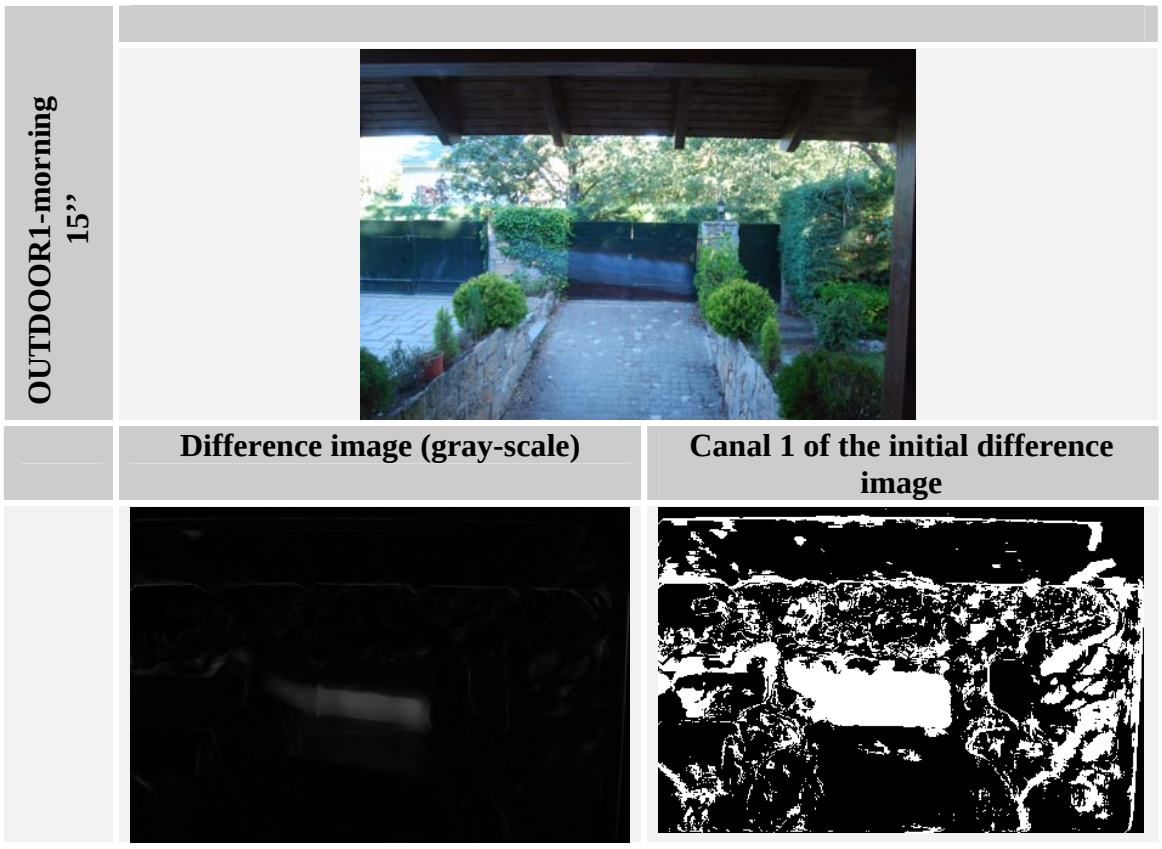


Figure Comparison of methods for activity detection of "new"/"old " objects

In the previous figure, can be observed that the Median Correction1 process is the only method that do not eliminate part of the contour of the original image of the canal 2.



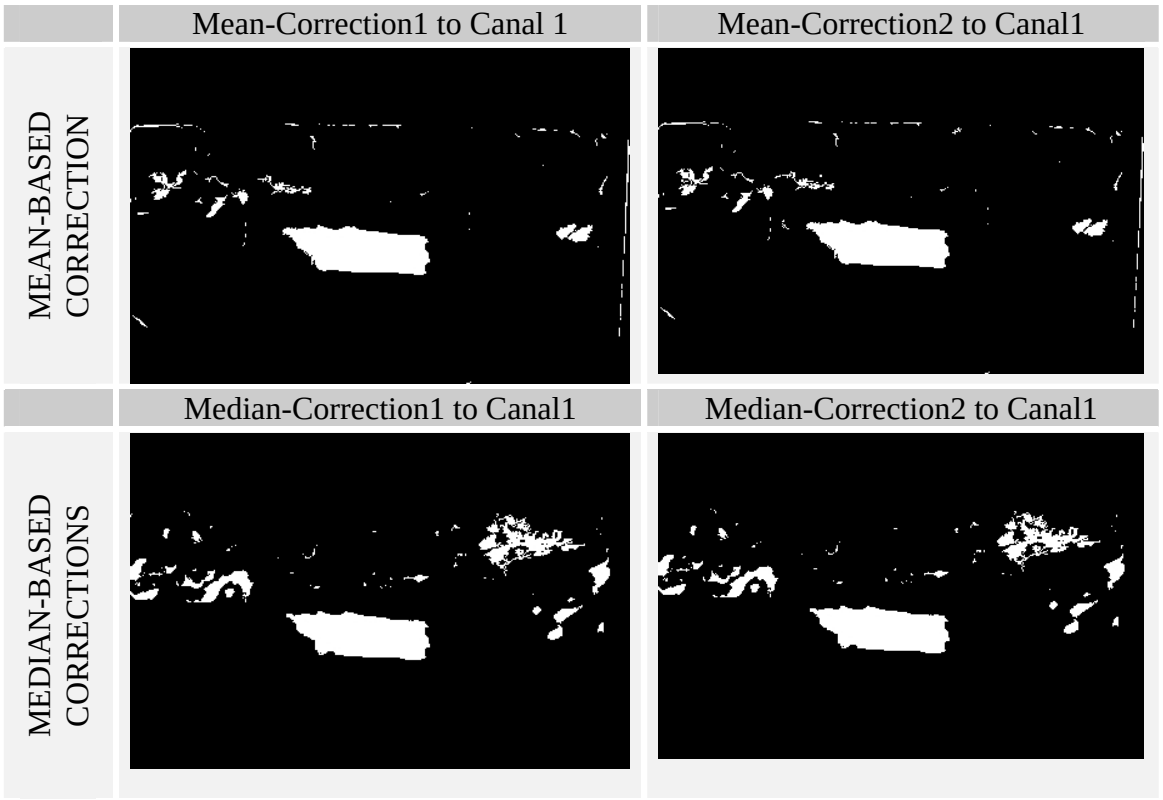
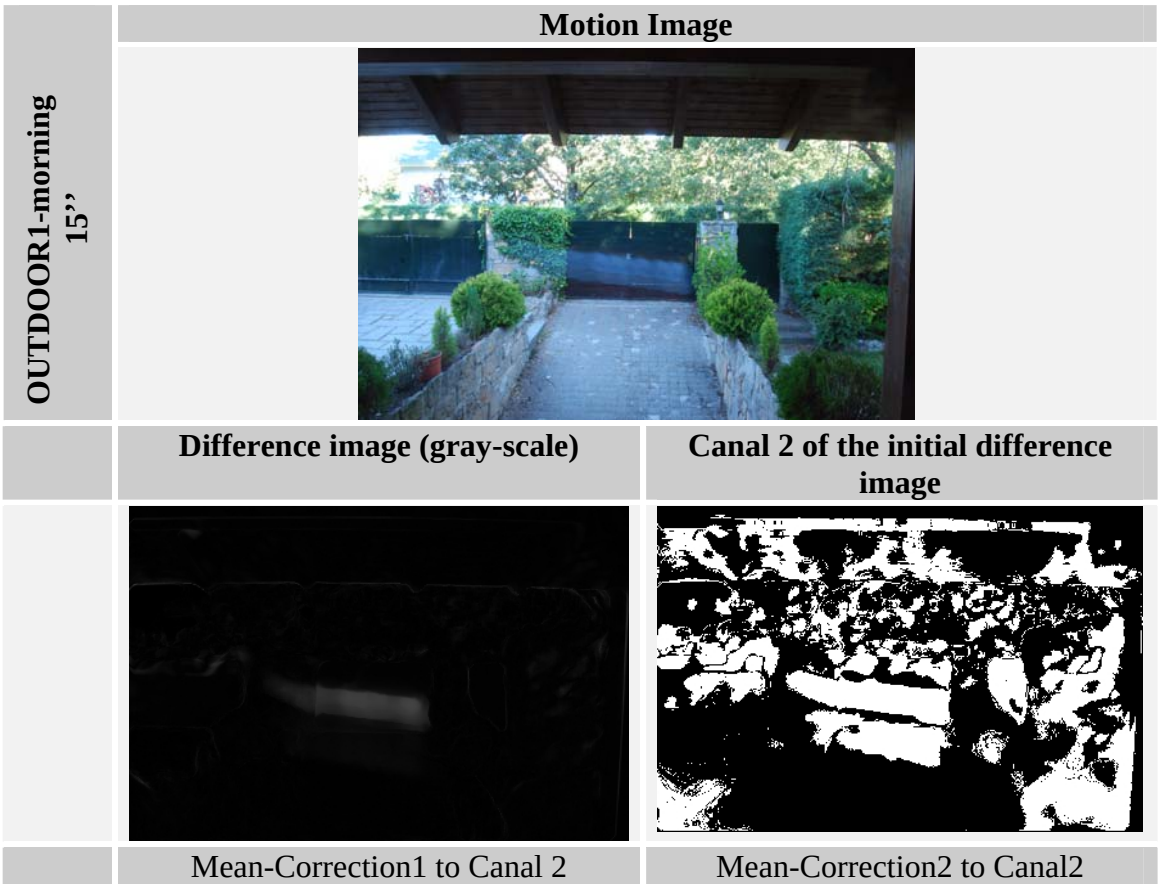


Figure Comparison of the effects of the different methods for activity detection of “new”/”old” objects on Canal1 of the initial difference image of an outdoor scenario



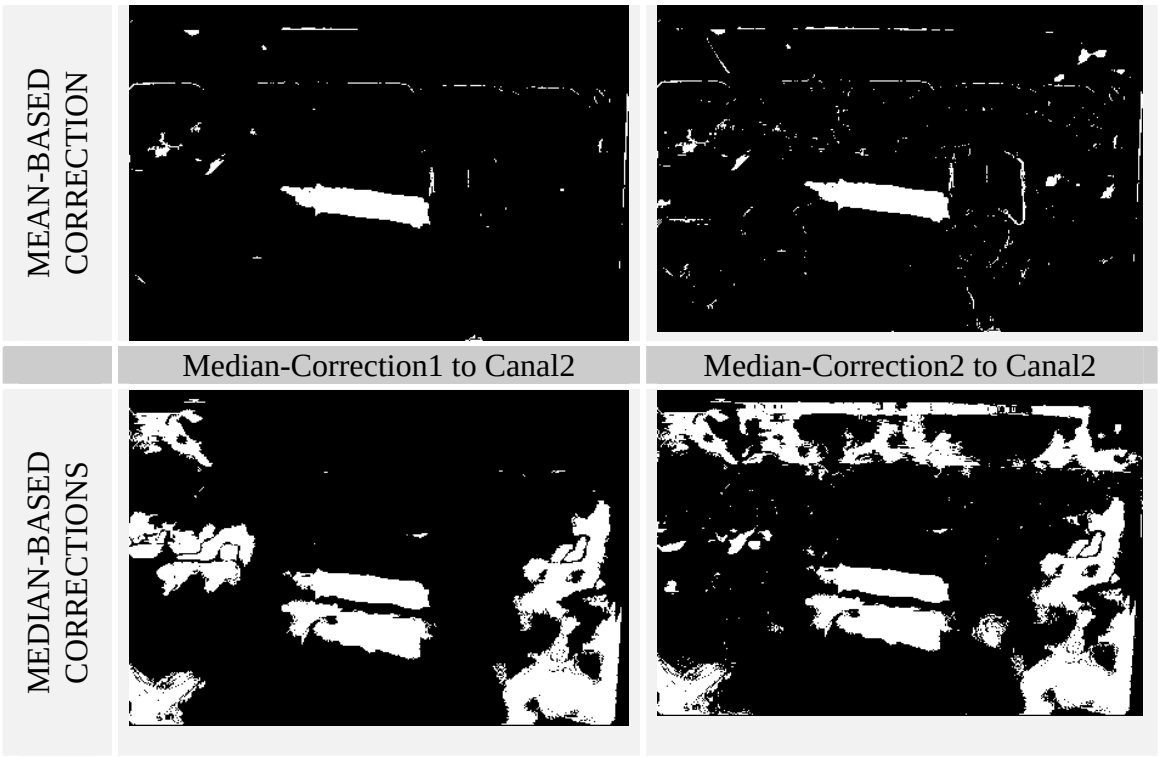


Figure Comparison of the effects of the different methods for activity detection of "new"/"old" objects on Canal2 of the initial difference image of an outdoor scenario

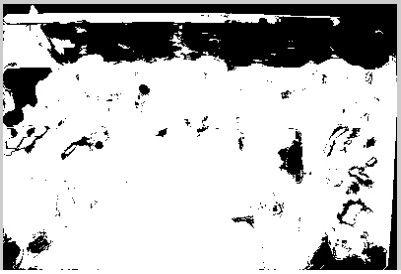
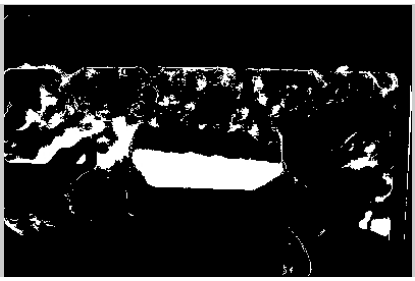
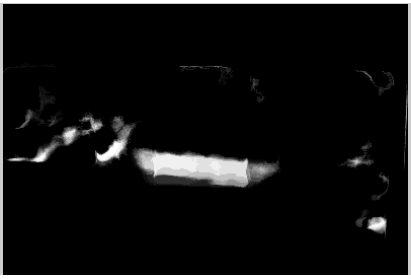
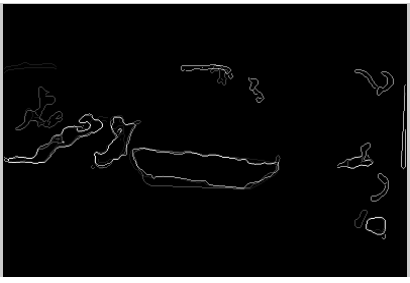
Analyzing the set of images on the two previous figures, it can be deduced that the **mean methods reduce in a better way, the areas belonging to movement of objects that were already on the background zone or/and their shadows**, whereas, the **corrections performed with median methods preserve better the form and area of the "new" object but do not extract at all the areas corresponding to shadows/movements of the "old" objects.**
Besides, the threshold used in Mean Correction1 seems to work better than the threshold of Mean Correction2. Also, the threshold used in Median Correction1 eliminates more "old object" area components than Median Correction 2.
Because of the reasons explained in the previous paragraphs, the methods of analysis selected has been **Mean Correction1** and **Median Correction1**, and their results will be showed and analyzed later.

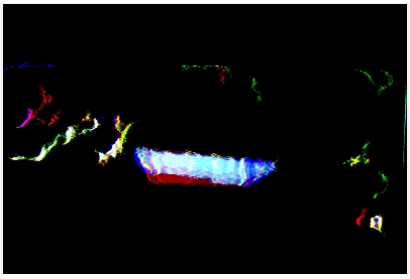
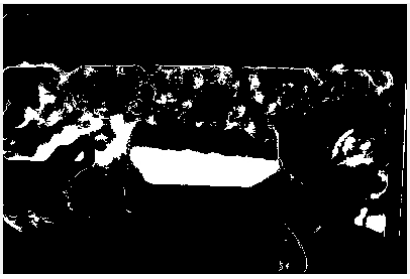
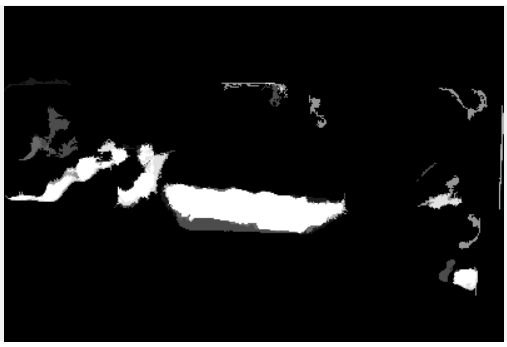
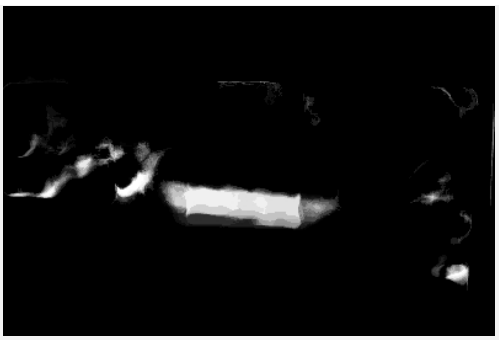
6.3. LIST OF RESULTS

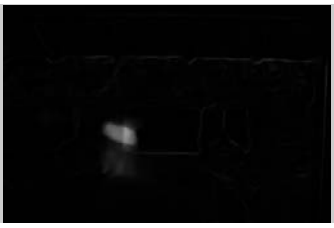
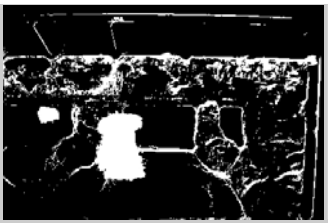
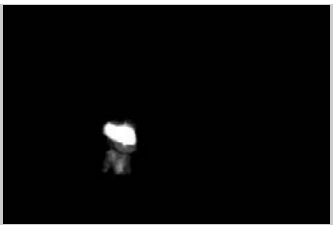
Here are listed the obtained results for all the exposures studied. However, some of the internal results obtained during the program execution are omitted, in order not to enlarge the report, but can be observed in the attached files.
Besides, the first table of the first scenario shows a complete example of the diverse program phases.

NOTE: The images marked with an * belongs to the Mean Correction1, but the equivalent images resulting from applying Median Correction1 are not showed in the table in order not to extend too much the report, but the program also shows them.

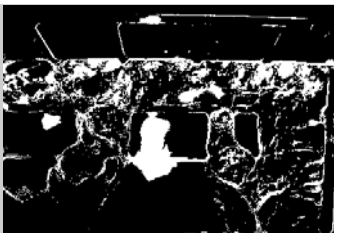
6.3.1. Median Filter

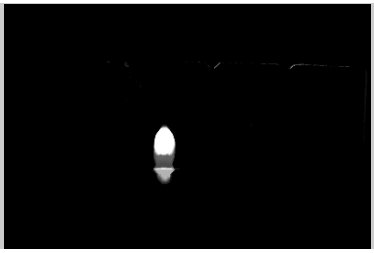
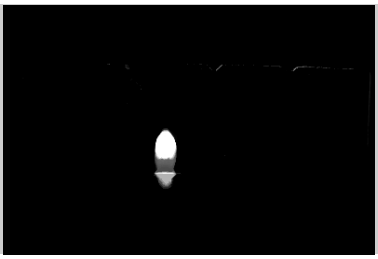
OUTDOOR1 Morning	
MOTION IMAGE	AVERAGE IMAGE
	
RGB DIFFERENCE IMAGE	DIFFERENCE IMAGE (GRAY-SCALE)
	
DIFFERENCE IMAGE(B&W)	DIFFERENCE: AFTER MEAN CORRECTION1
	
FINAL IMAGE (EXTREME MOTIONS).(Mean-Correction1)	FINAL IMAGE (PROGRESSIVE MOTION SCALE)(Mean-Correction1)
	
CANNY EDGE DETECTOR*	BOUNDARY EXTRACTION*
	

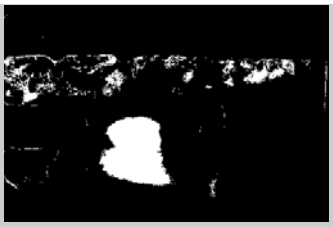
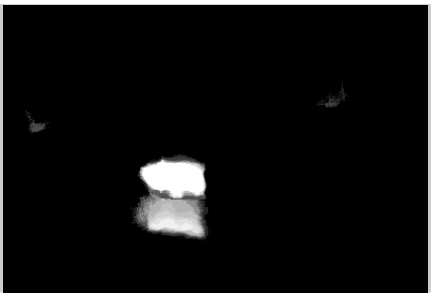
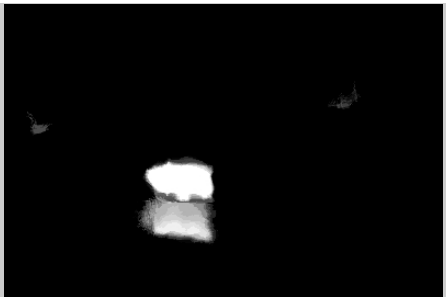
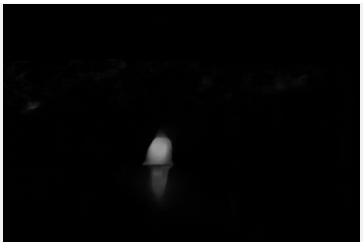
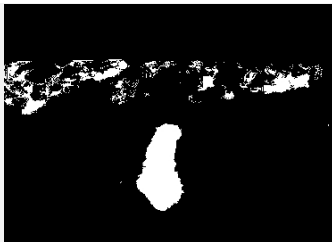
	DEBLURRED IMAGE*	DIFFERENCE: AFTER MEDIAN CORRECTION1
		
	FINAL IMAGE:EXTREME MOTIONS.(Median Correction1)	FINAL IMAGE:PROGRESSIVE MOTIONS(Median Correction1)
		

Shutter	OUTDOOR1 Morning			
1''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		

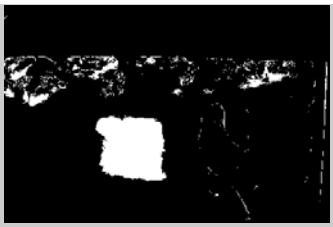
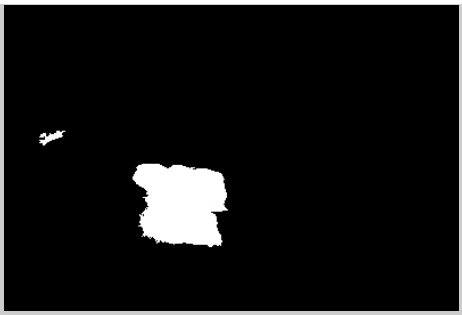
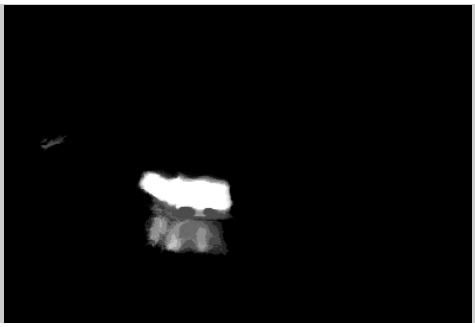
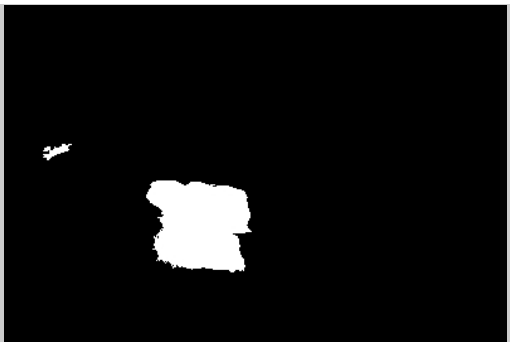
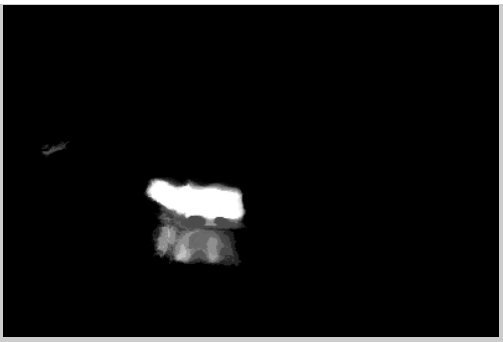
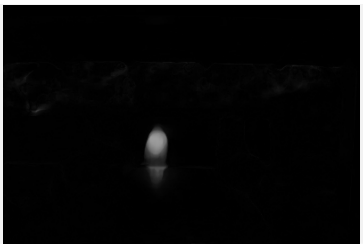
PARALLEL(C)

	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
DIFFERENCE IMAGE			

	B&W RESULT	GRAY-SCALE RESULT
MEAN CORRECTION1		
MEDIAN CORRECTION1		

Shutter	OUTDOOR1 Morning				
1.3’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		

Shutter	OUTDOOR1 Morning				
1.6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
		
MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
		

OUTDOOR1
Morning

2’’

ORTHOGONAL(B)

DIFFERENCE IMAGE

MOTION IMAGE

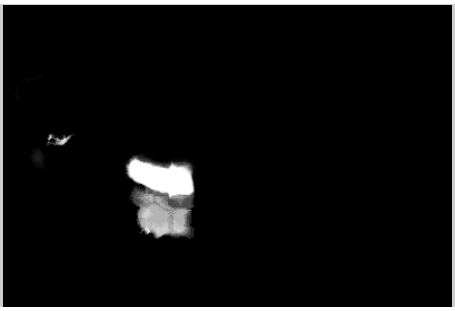
DIFFERENCE (GRAY-SCALE)

B&W DIFFERENCE

MEAN CORRECTION1

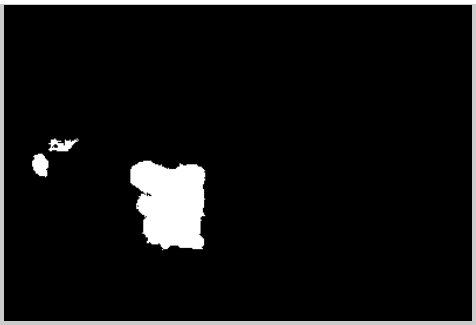
B&W RESULT

GRAY-SCALE RESULT

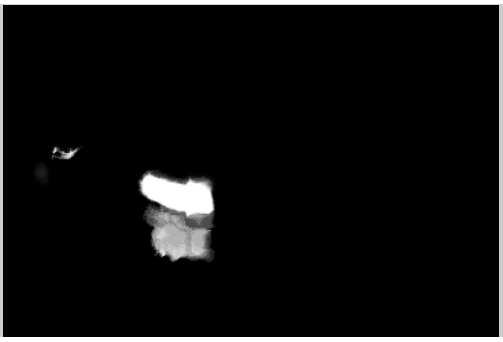


MEDIAN CORRECTION1

B&W RESULT



GRAY-SCALE RESULT



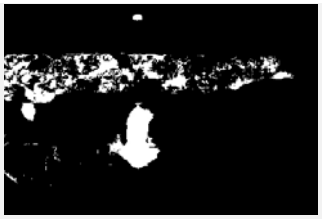
PARALLEL(C)

DIFFERENCE IMAGE

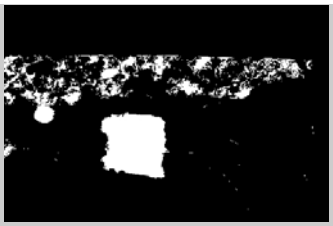
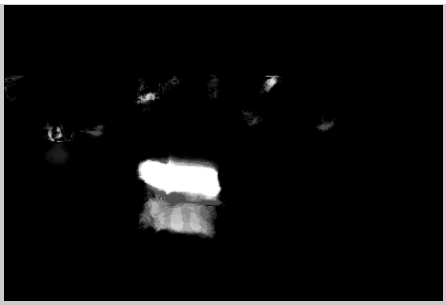
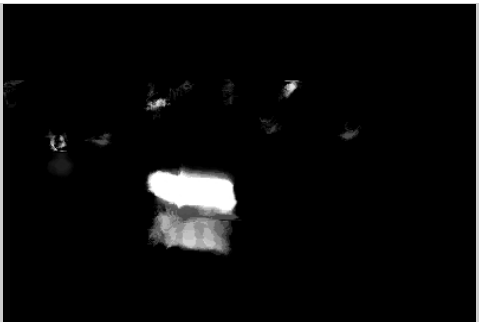
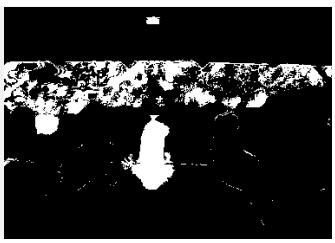
MOTION IMAGE

DIFFERENCE (GRAY-SCALE)

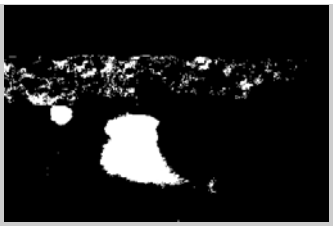
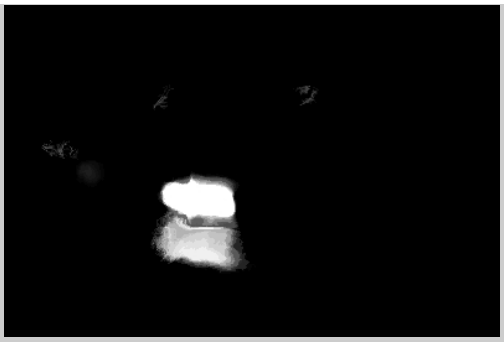
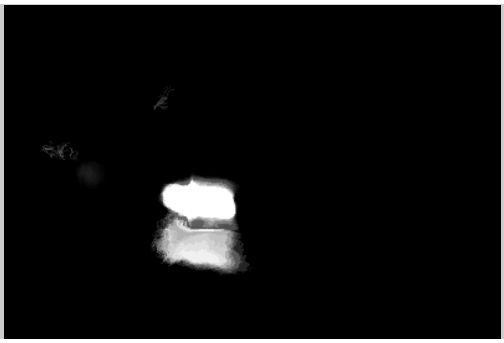
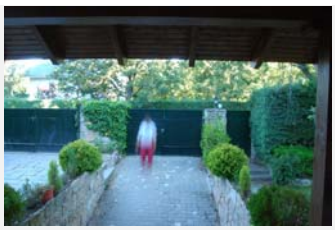
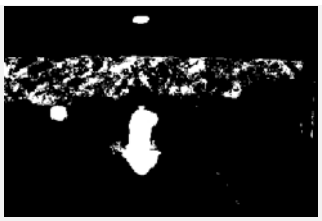
B&W DIFFERENCE



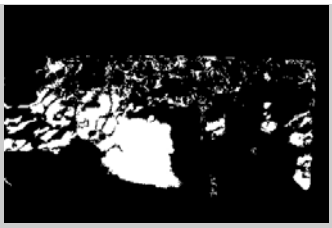
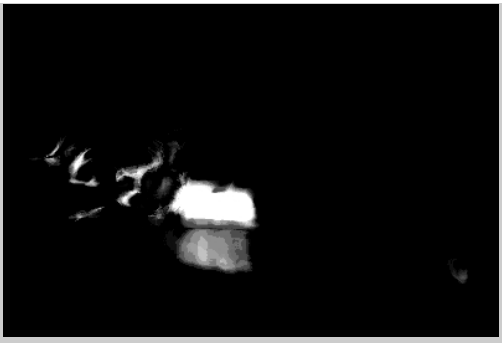
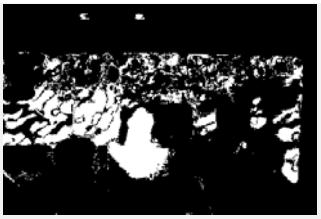
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Morning			
2.5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

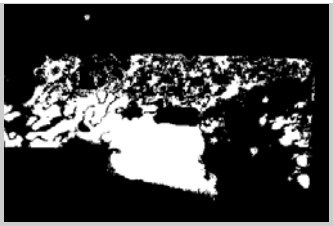
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Morning				
3’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

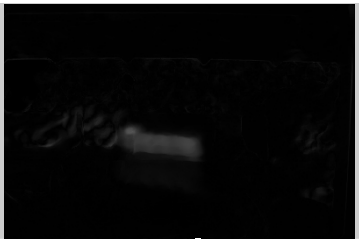
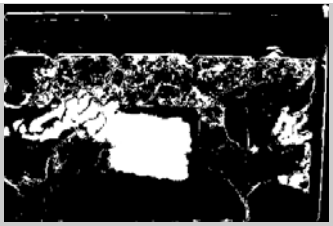
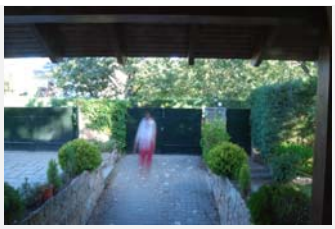
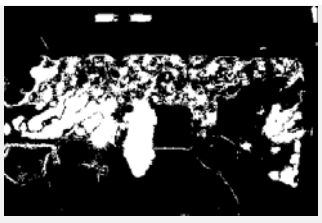
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

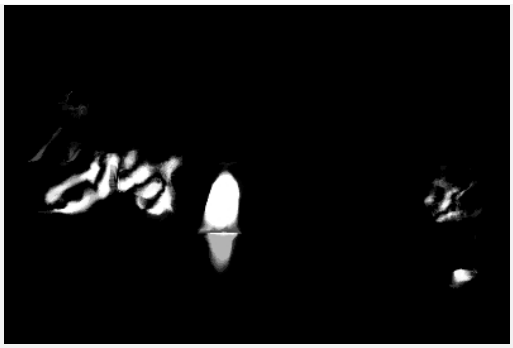
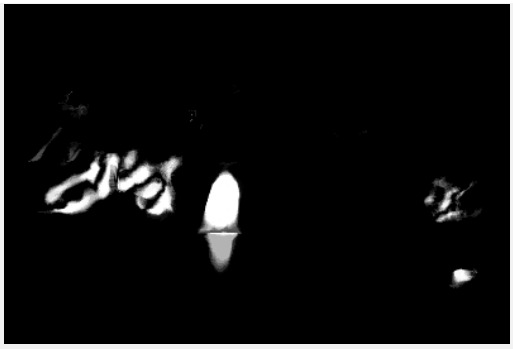
Shutter	OUTDOOR1 Morning			
4''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

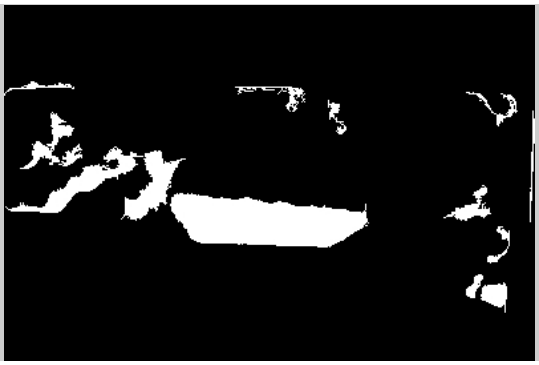
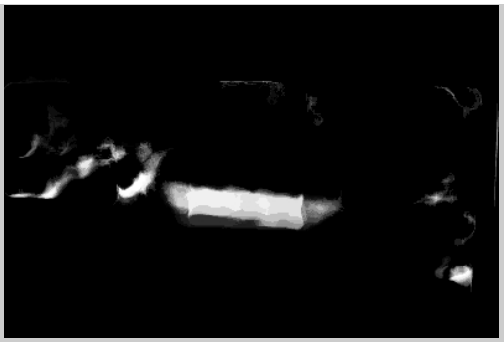
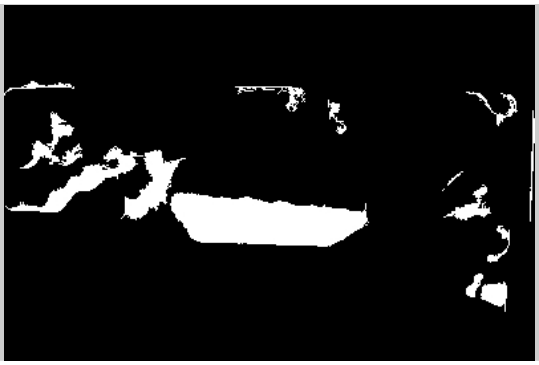
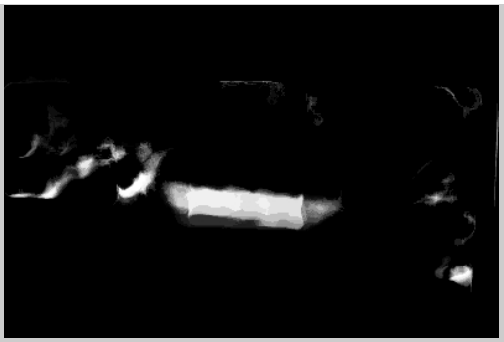
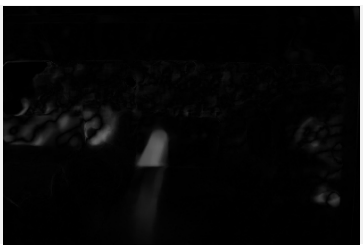
		B&W RESULT	GRAY-SCALE RESULT
MEDIAN CORRECTION1			

Shutter			OUTDOOR1 Morning		
5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

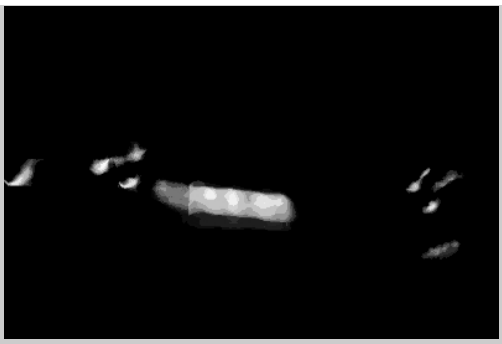
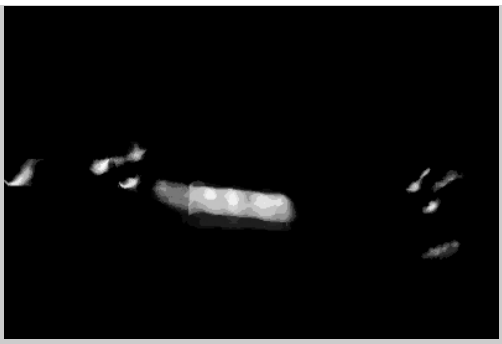
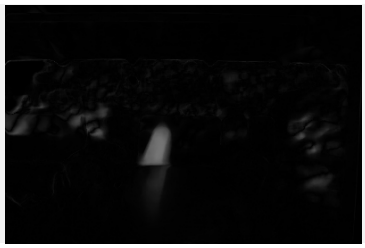
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
		MEDIAN CORRECTION1		

Shutter			OUTDOOR1 Morning		
6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

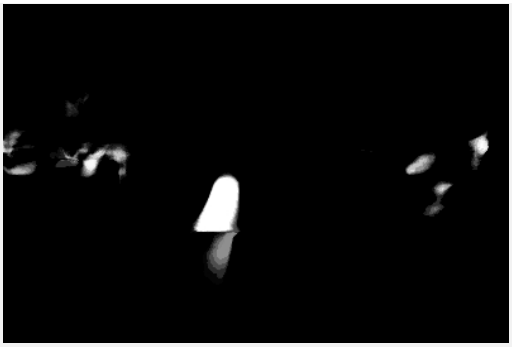
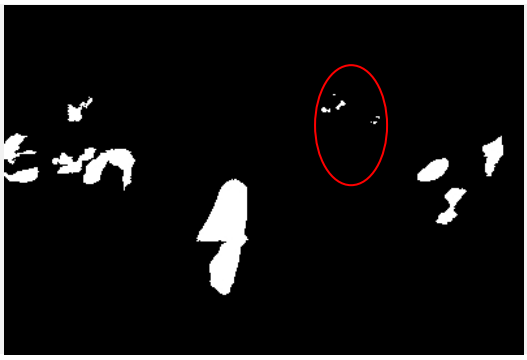
Shutter	OUTDOOR1 Morning			
8’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

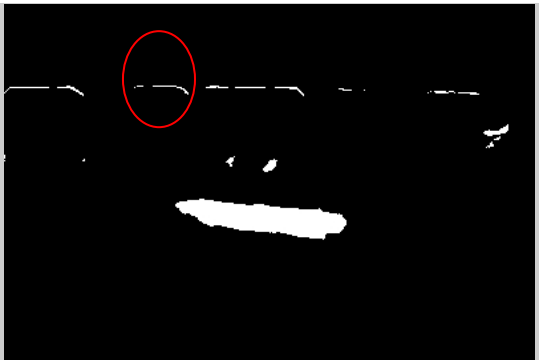
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Morning			
10''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

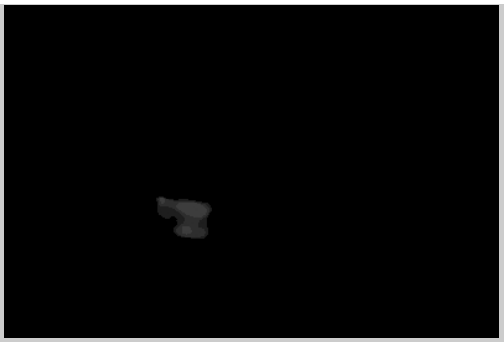
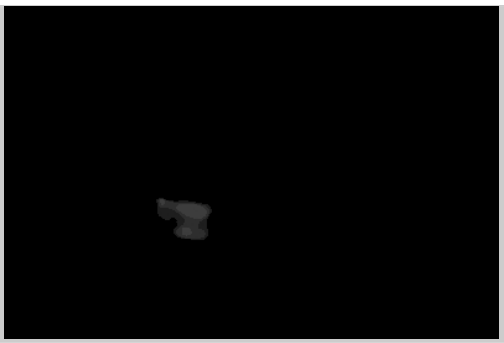
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

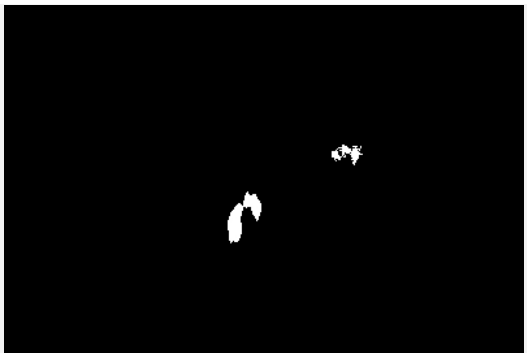
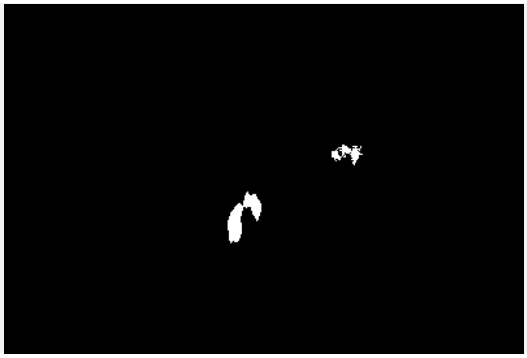
Shutter	OUTDOOR1 Morning				
15''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

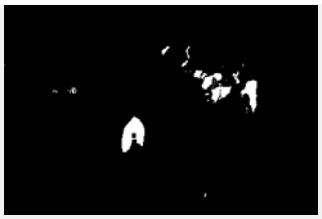
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
		MEDIAN CORRECTION1		

Shutter	OUTDOOR1 Morning			
20''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

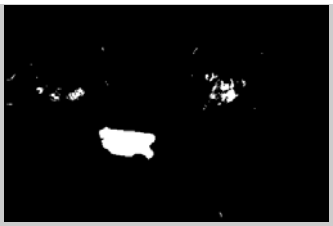
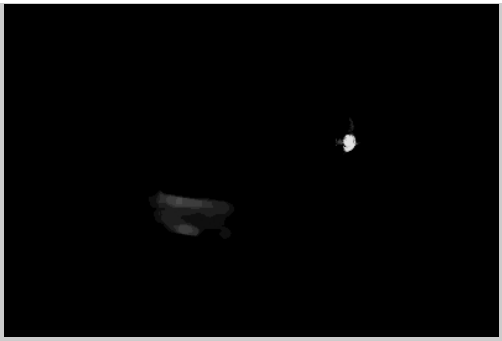
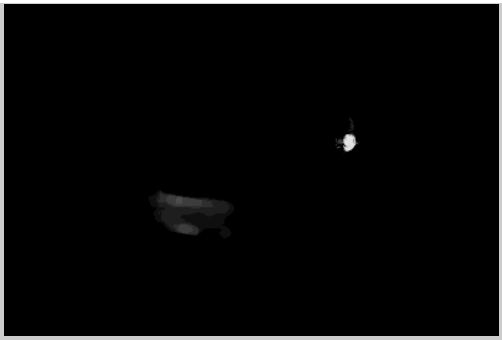
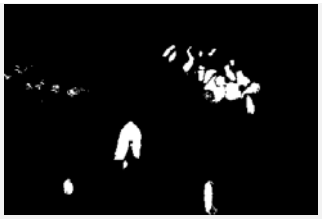
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

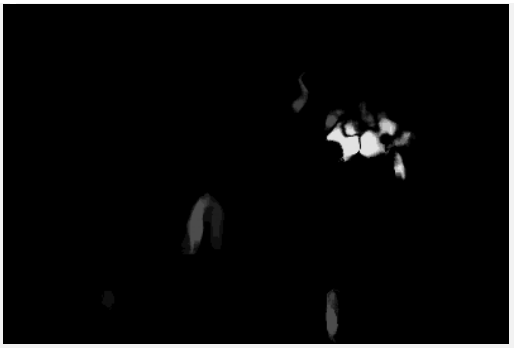
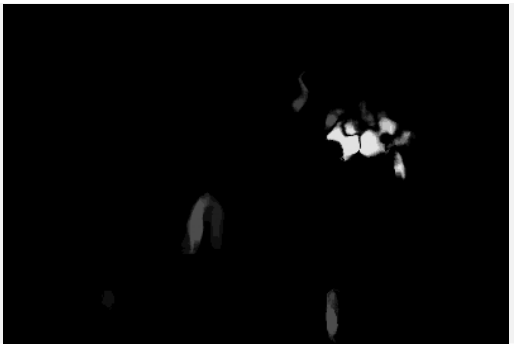
Shutter	OUTDOOR1 Night				
1''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

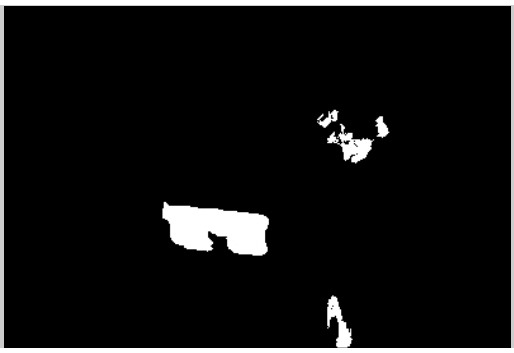
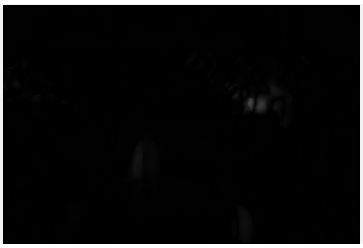
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

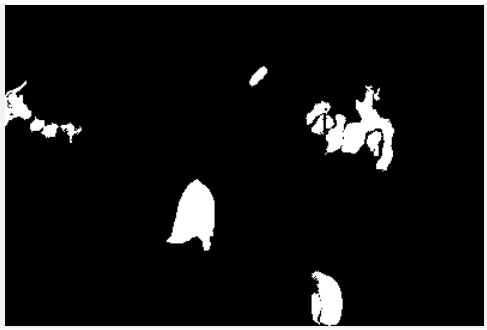
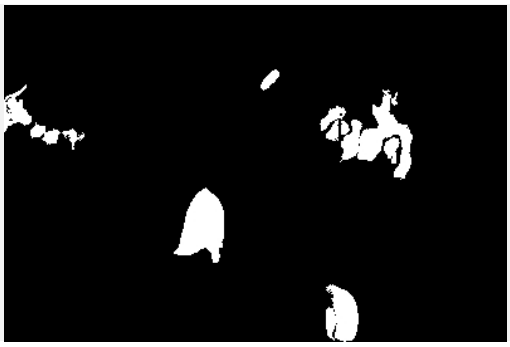
Shutter	OUTDOOR1 Night			
1.3''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

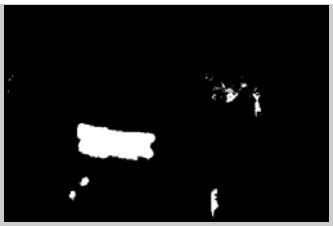
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

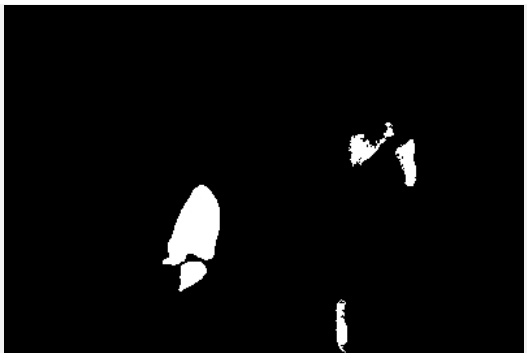
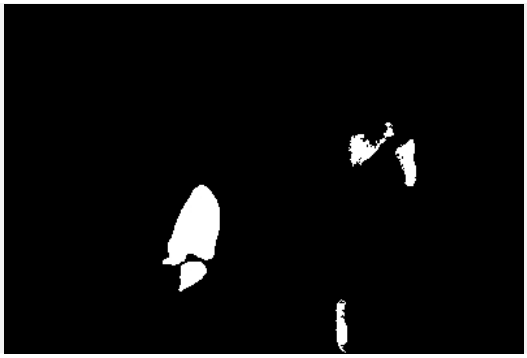
Shutter	OUTDOOR1 Night			
1.6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

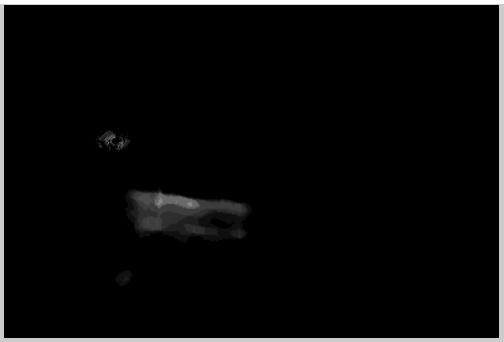
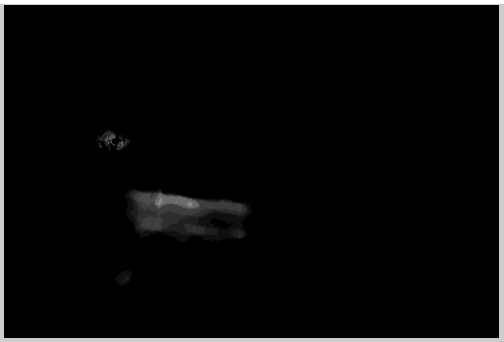
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

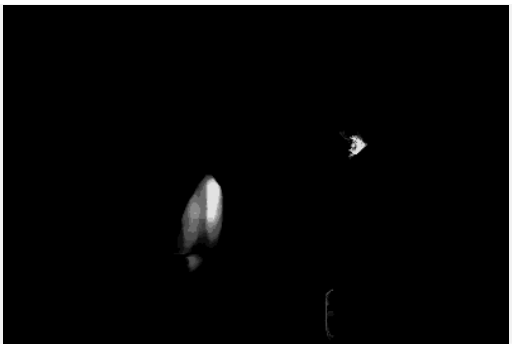
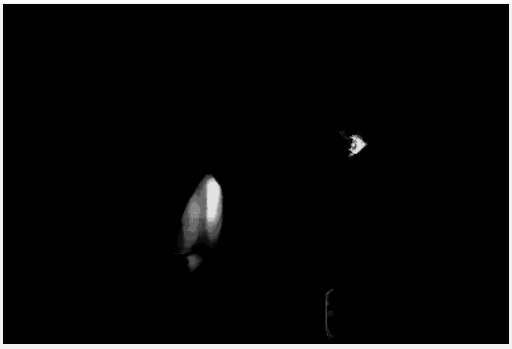
Shutter	OUTDOOR1 Night				
2’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

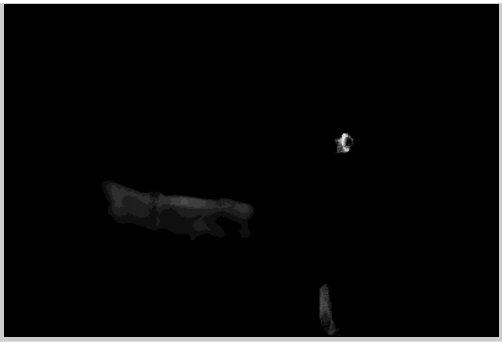
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
		MEDIAN CORRECTION1	B&W RESULT 	GRAY-SCALE RESULT 

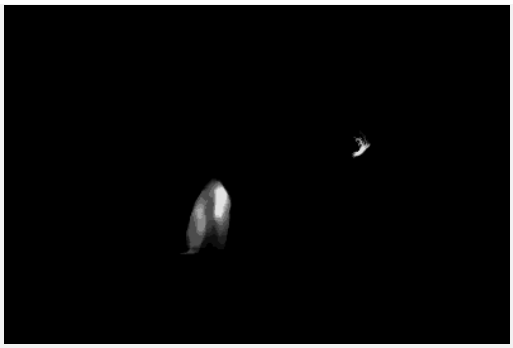
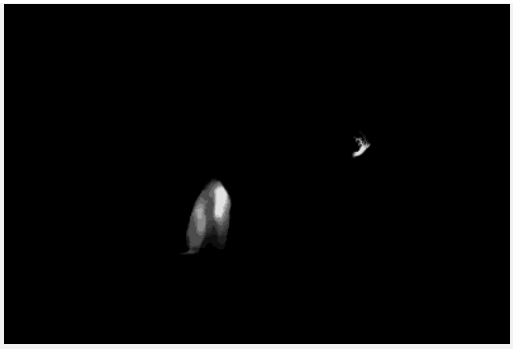
Shutter	OUTDOOR1 Night			
2.5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

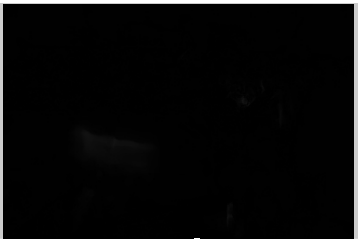
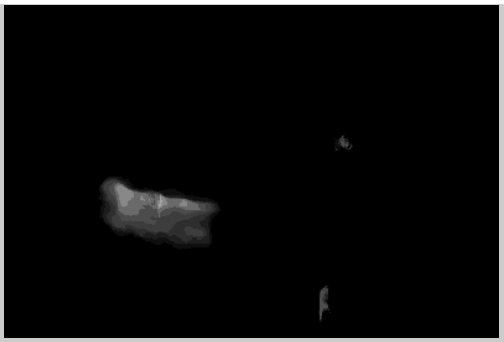
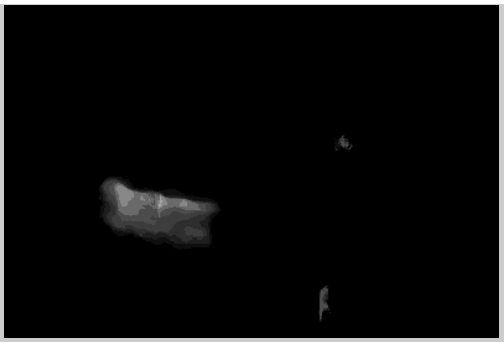
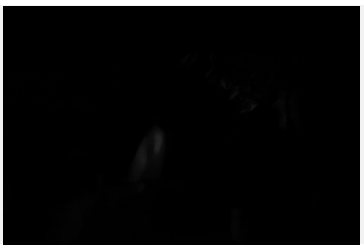
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

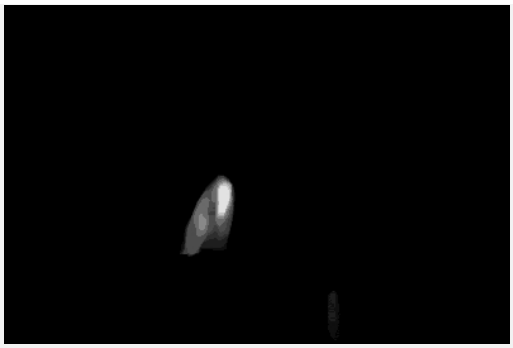
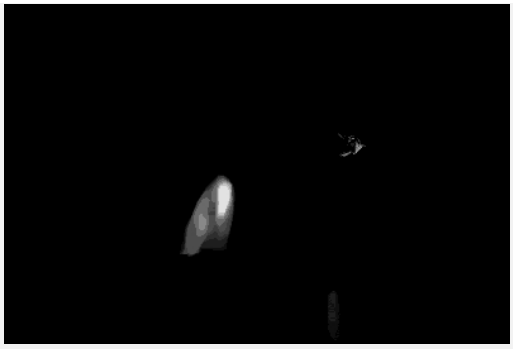
Shutter	OUTDOOR1 Night				
3’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
			B&W RESULT		GRAY-SCALE RESULT
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

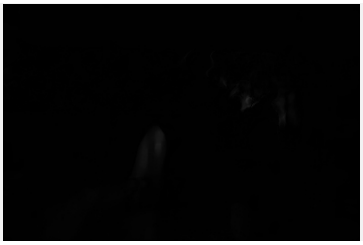
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Night				
4’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

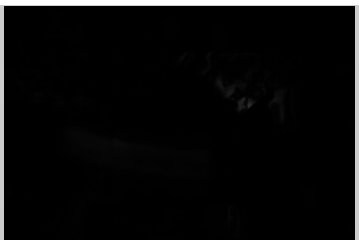
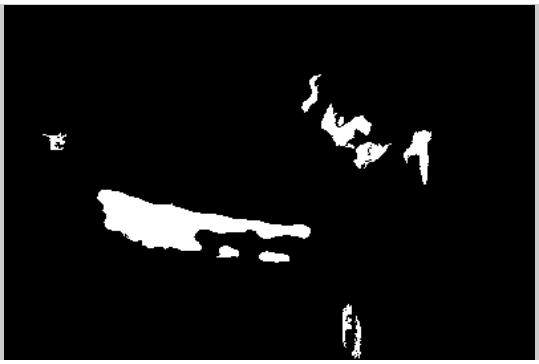
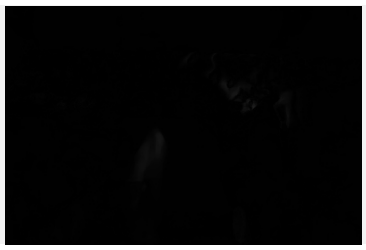
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter			OUTDOOR1 Night		
5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

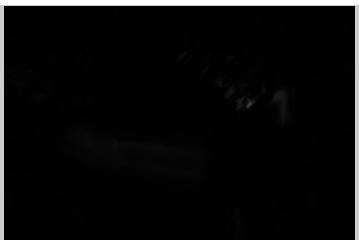
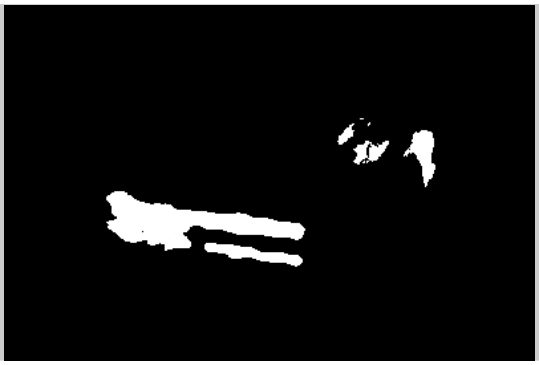
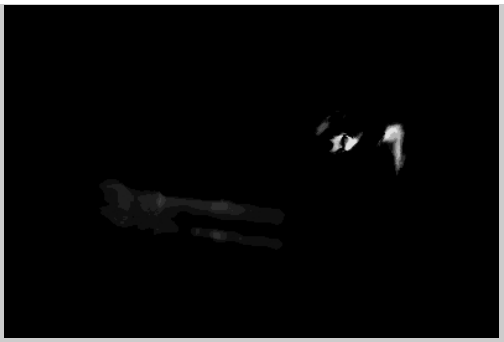
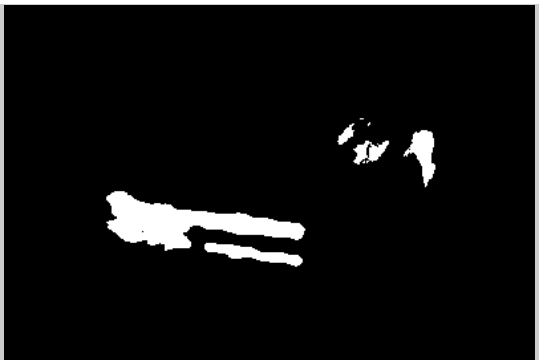
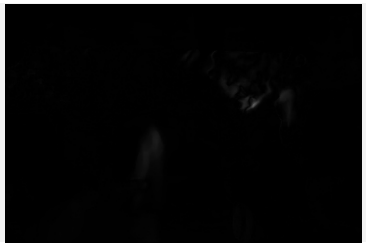
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Night			
6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

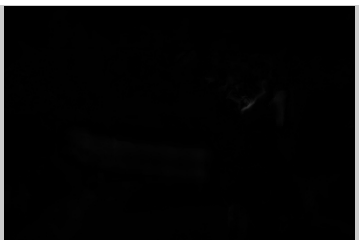
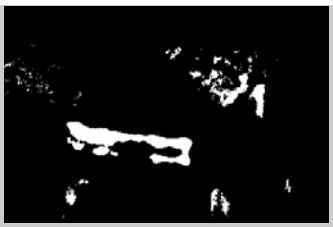
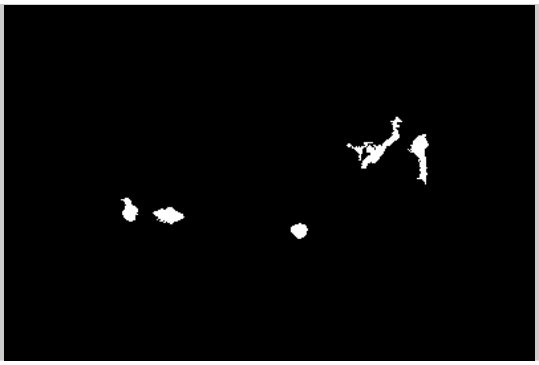
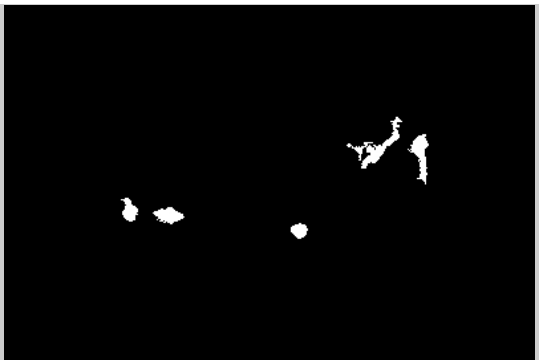
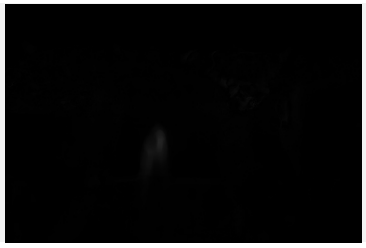
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
		MEDIAN CORRECTION1	B&W RESULT 	GRAY-SCALE RESULT 

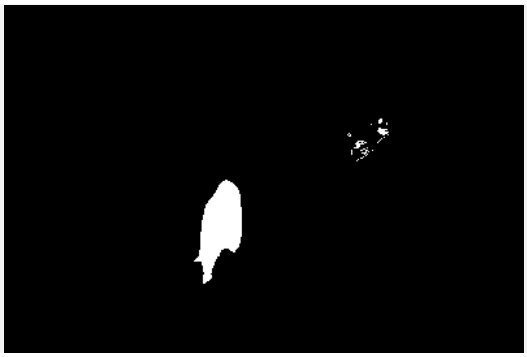
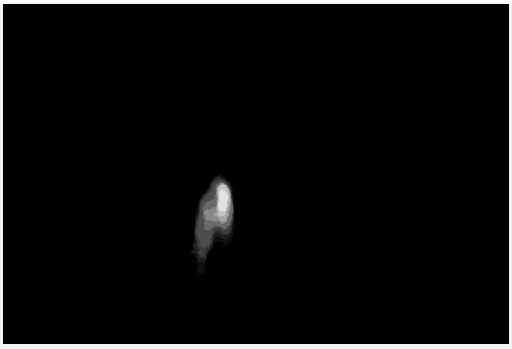
Shutter	OUTDOOR1 Night			
8''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

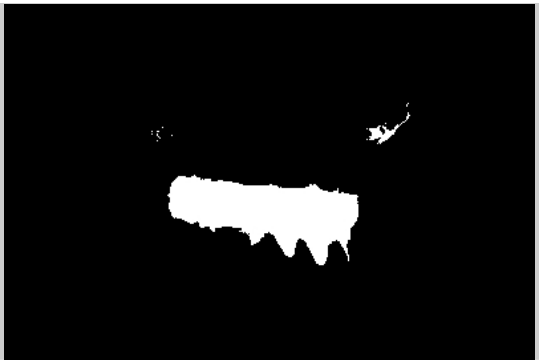
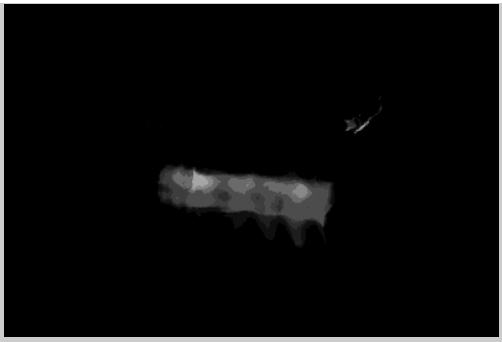
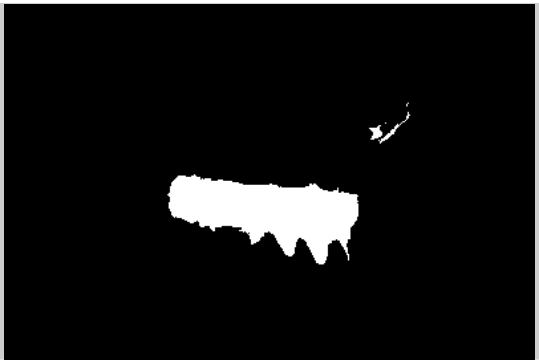
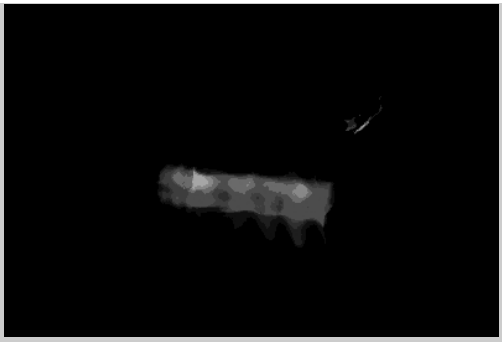
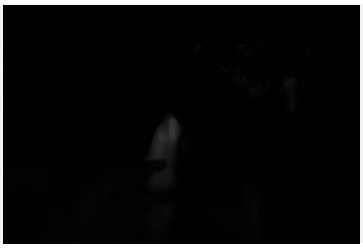
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

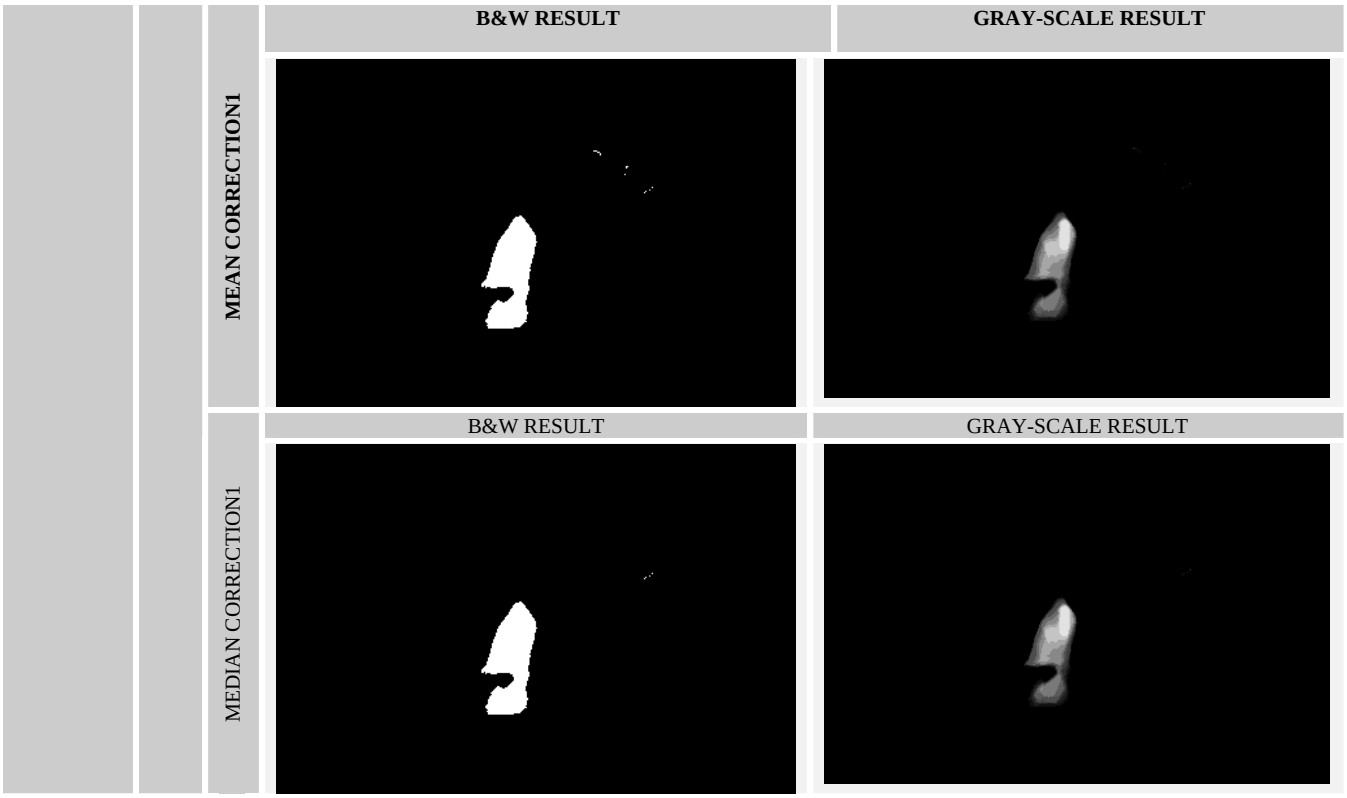
Shutter	OUTDOOR1 Night				
10''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR1 Night				
15''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

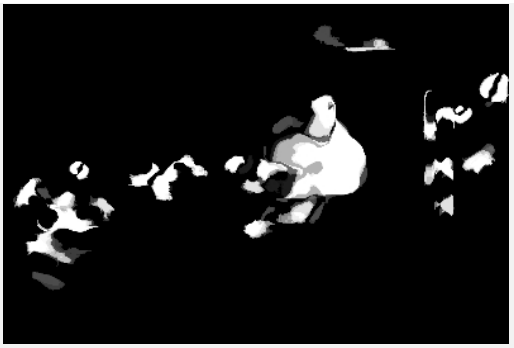
		MEAN CORRECTION1	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

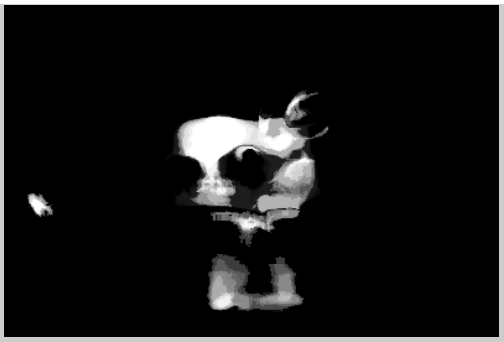
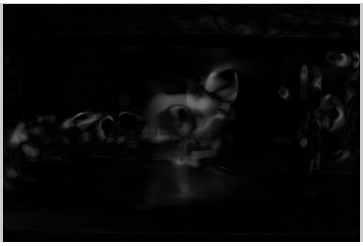
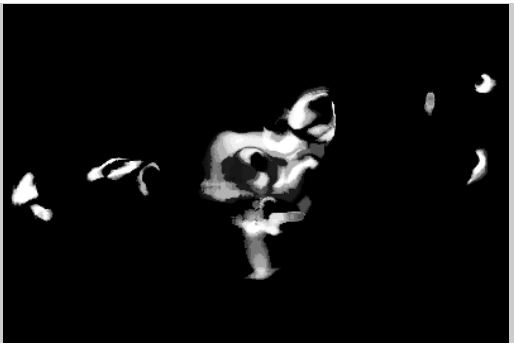
Shutter	OUTDOOR1 Night				
20''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

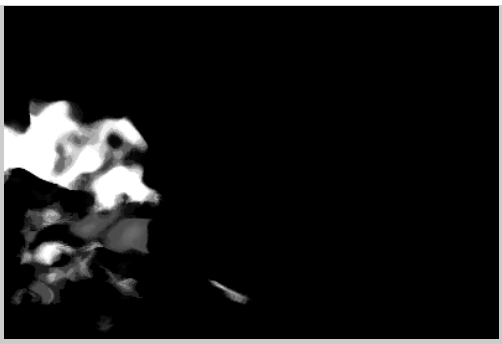
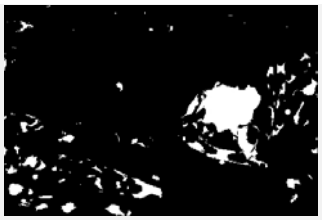


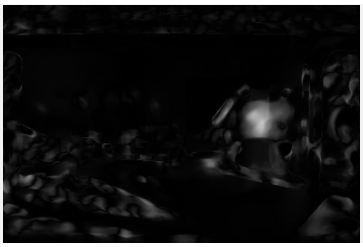
From now, when the mean correction1 results are very similar to that performed by median correction1 method, these last results are omitted, although, they can be observed in the attached files.

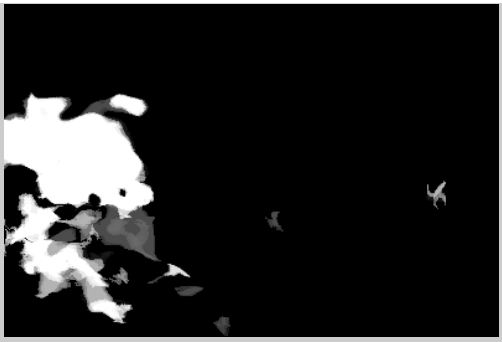
In the next series, which corresponds to OUTDOOR2-morning, the **shadows to the movement of branches in front of the scenario influenced considerably the activity detection process.**

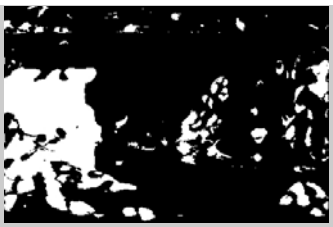
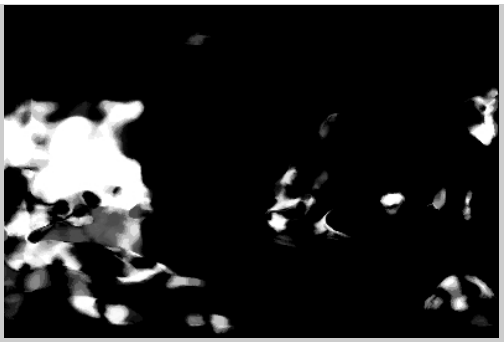
Shutter	OUTDOOR2 morning			
1''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

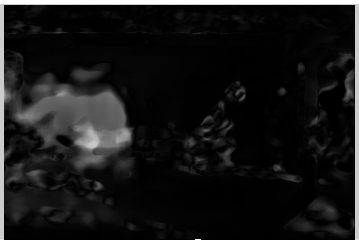
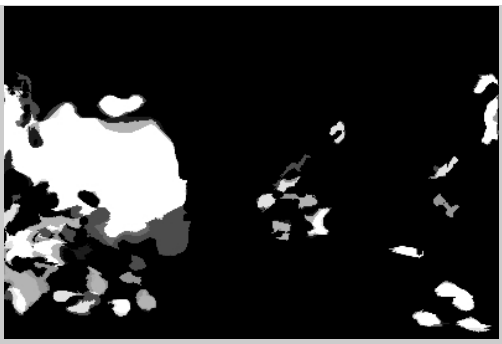
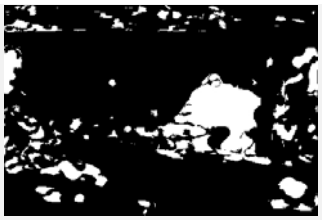
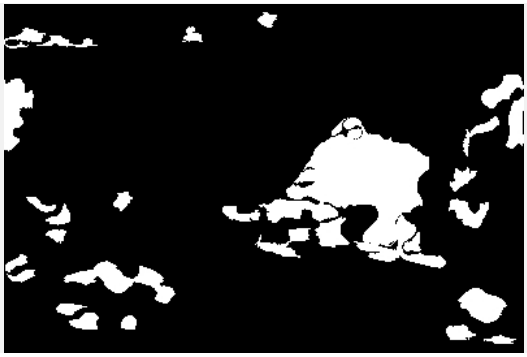
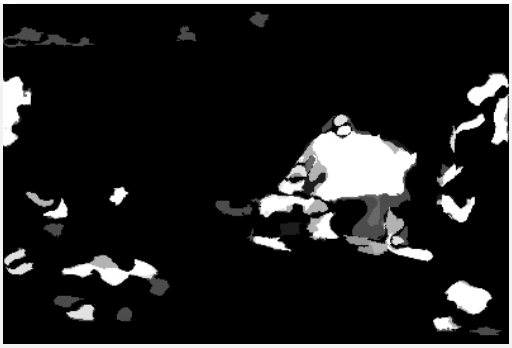
Shutter			OUTDOOR2 Morning		
			MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
1.3’	ORTHOGONAL(B)	DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT 	GRAY-SCALE RESULT 	
			MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
	DIAGONAL(C)	DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT 	GRAY-SCALE RESULT 	

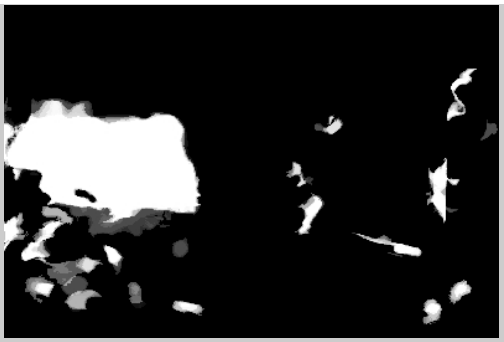
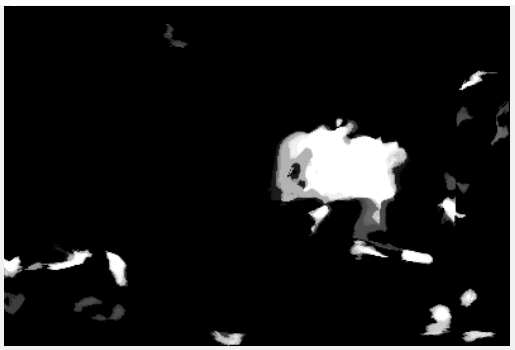
Shutter	OUTDOOR2 Morning			
1.6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

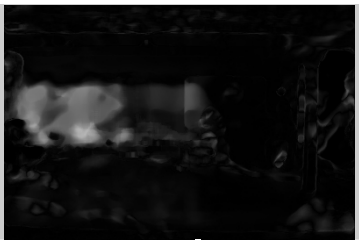
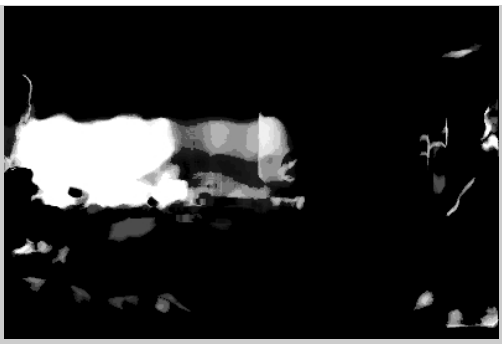
Shutter	OUTDOOR2 Morning			
2’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

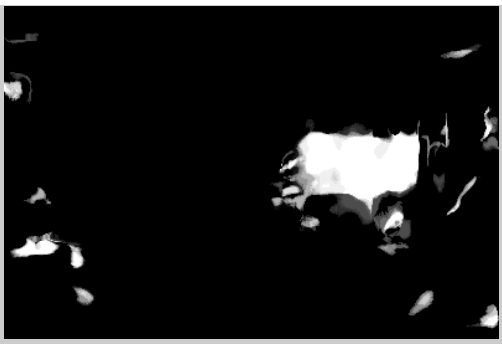
Shutter	OUTDOOR2 morning			
2.5’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

Shutter			OUTDOOR2 morning		
3''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					
	DIAGONAL (C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					

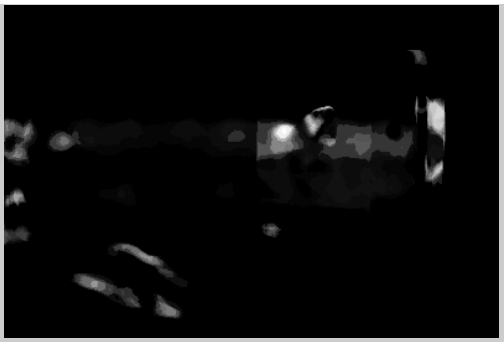
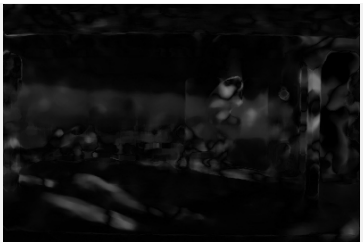
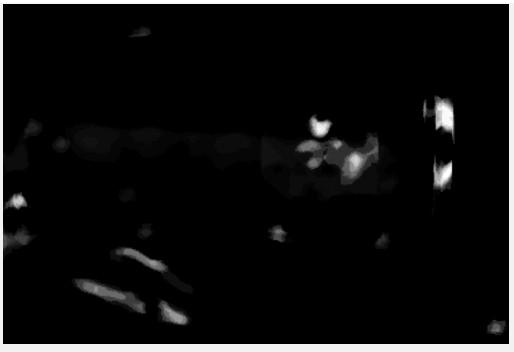
Shutter	OUTDOOR2 morning				
4''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

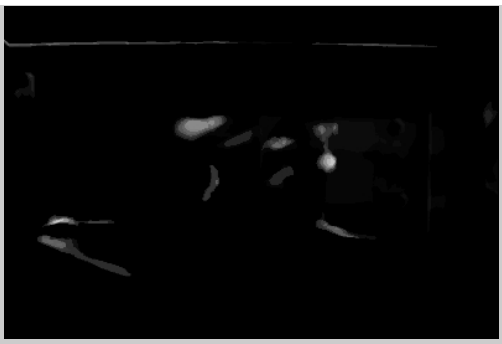
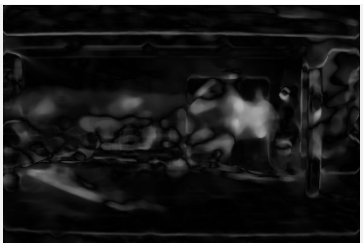
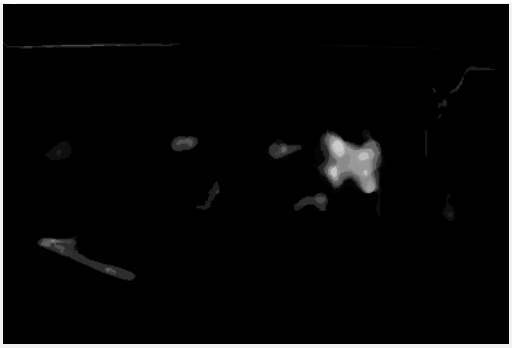
Shutter			OUTDOOR2 morning		
5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

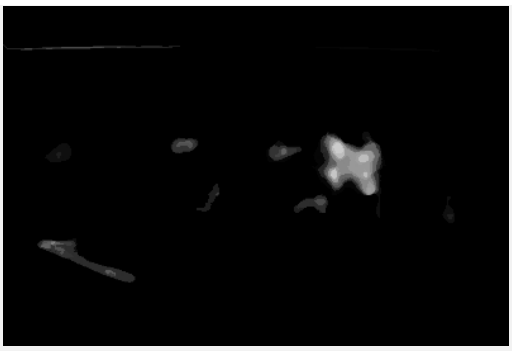
Shutter	OUTDOOR2 Morning			
6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

Shutter		OUTDOOR2 morning		
		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
8''	ORTHOGONAL(B) DIFFERENCE IMAGE			
	ORTHOGONAL(B) MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
				
		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
	DIAGONAL(C) DIFFERENCE IMAGE			
	DIAGONAL(C) MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
				

Shutter	OUTDOOR2 morning			
10''	ORTHOGONAL(B)	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
	DIFFERENCE IMAGE			
	MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
				
		B&W RESULT		GRAY-SCALE RESULT
	DIAGONAL(C)	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
	DIFFERENCE IMAGE			
	MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
				

Shutter	OUTDOOR2 morning			
15''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

Shutter	OUTDOOR2 morning			
20''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		

In the next set of series: OUTDOOR2-Night, great changes of luminance happened during the twilight. This is the reason why the images corresponding to short shutter speeds the objects composing the images are clearly visible whereas for long shutter speeds it is impossible to distinguish any object.

Shutter			OUTDOOR2 Night		
1''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			

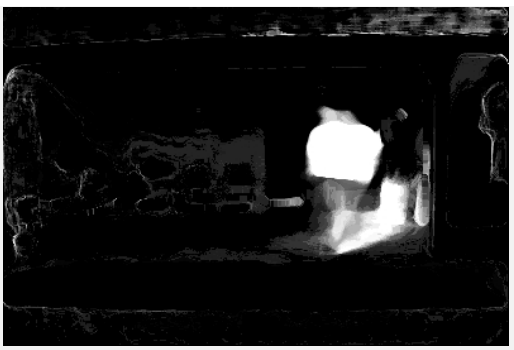
DIAGONAL(C)

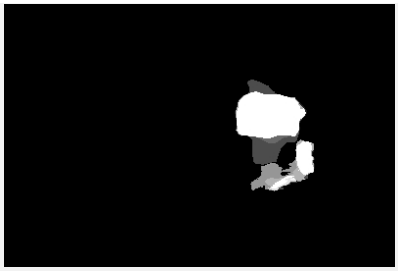
MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		

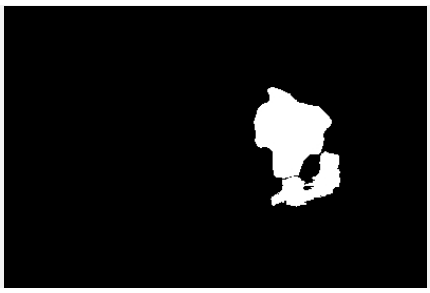
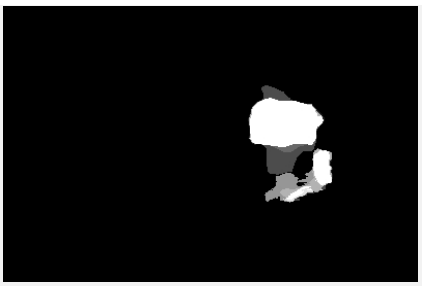
MEAN CORRECTION1

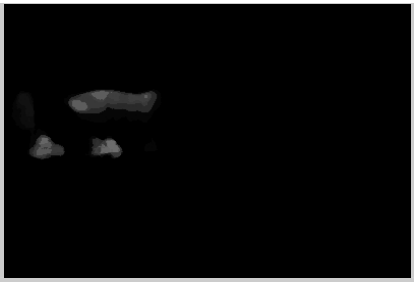
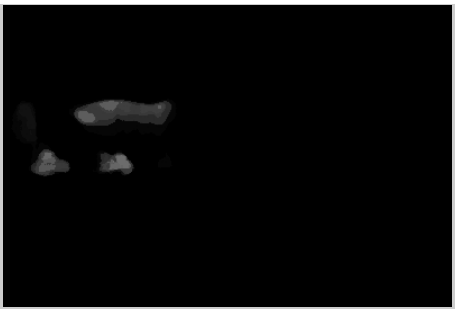
B&W RESULT	GRAY-SCALE RESULT
	

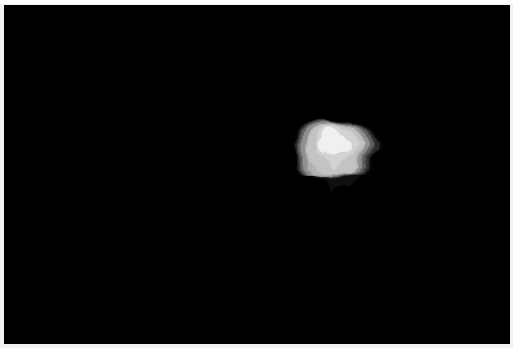
MEDIAN CORRECTION1

B&W RESULT	GRAY-SCALE RESULT
	

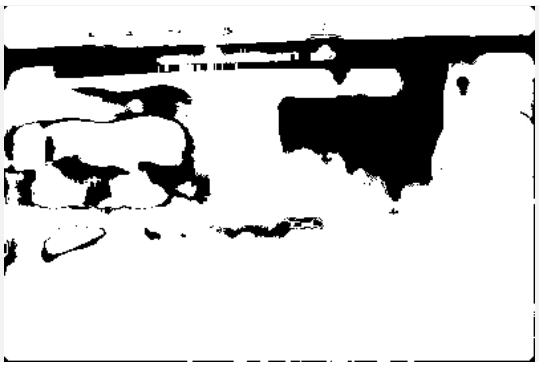
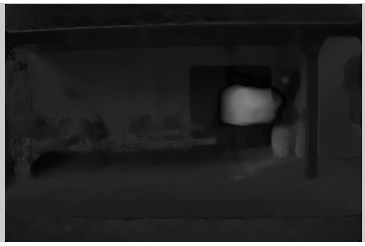
Shutter	OUTDOOR2 Night			
1.3''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR2 Night			
1.6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

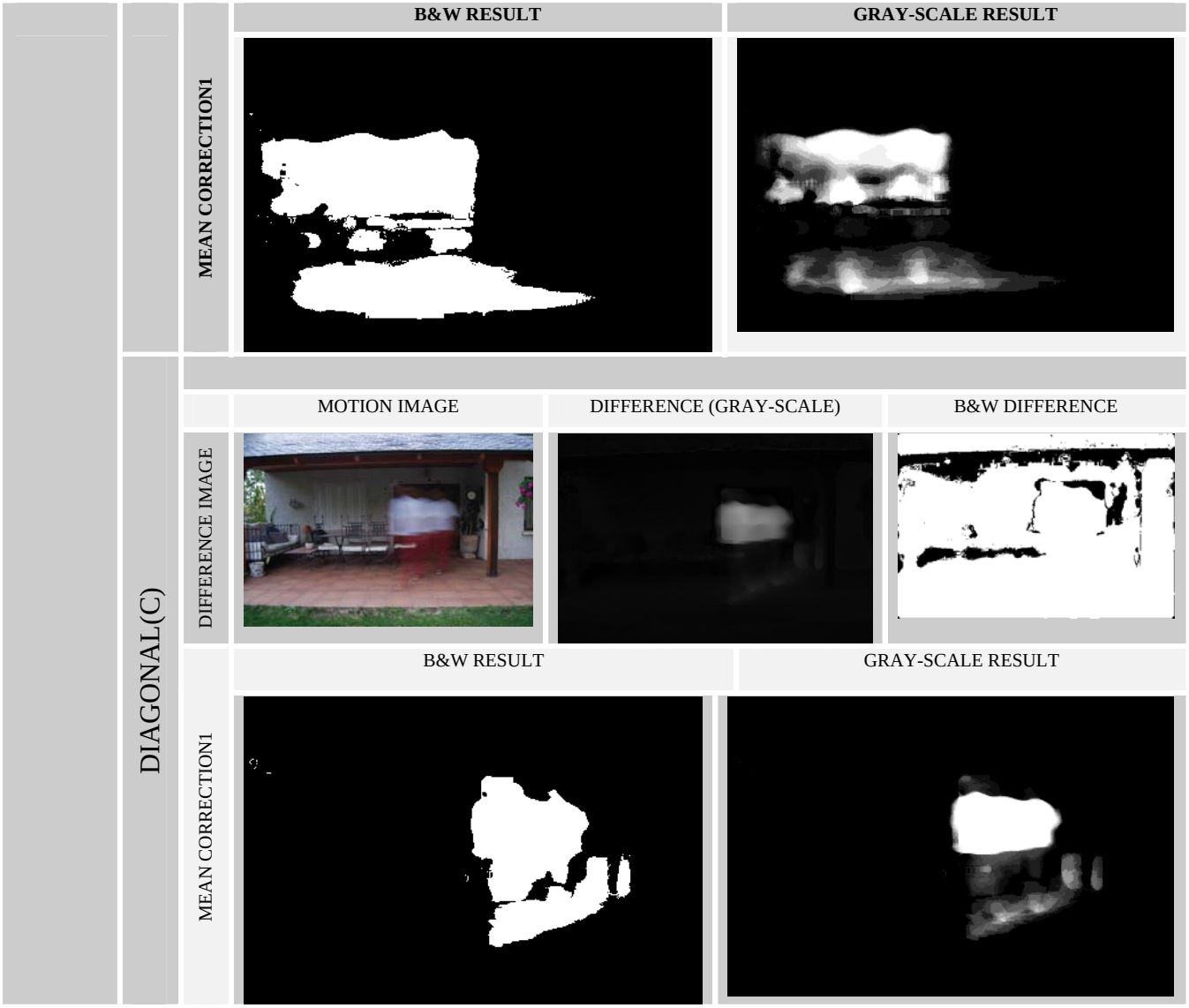
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

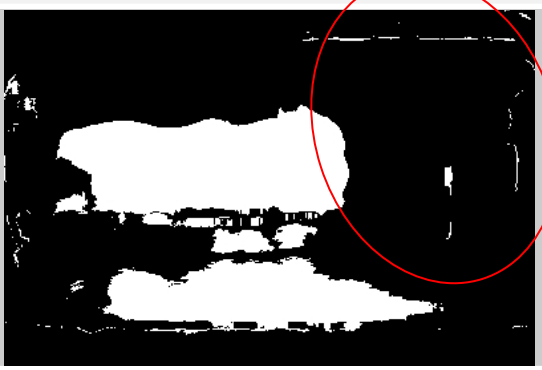
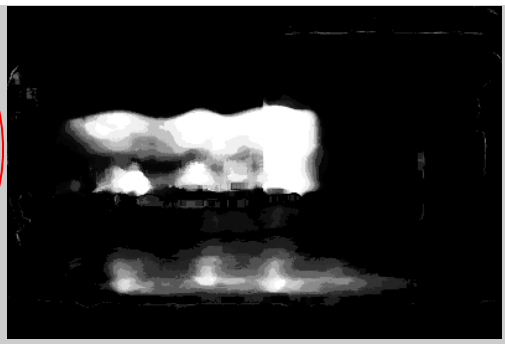
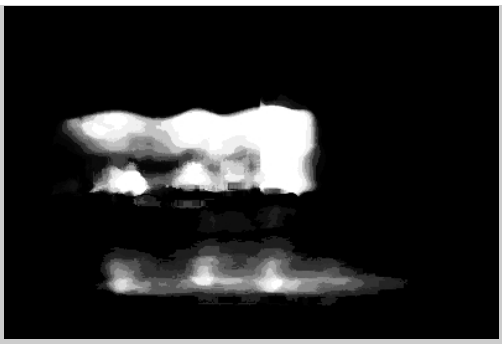
Shutter	**OUTDOOR2** Night			
2’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

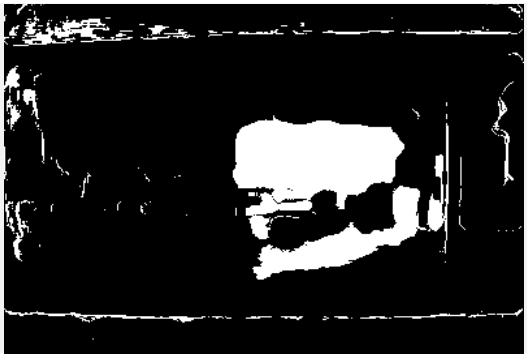
	DIAGONAL(C)	MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				
		DIFFERENCE IMAGE	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)
				
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

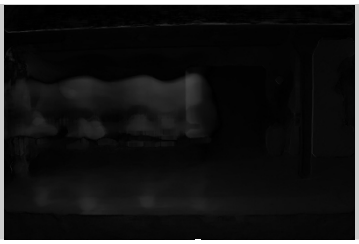
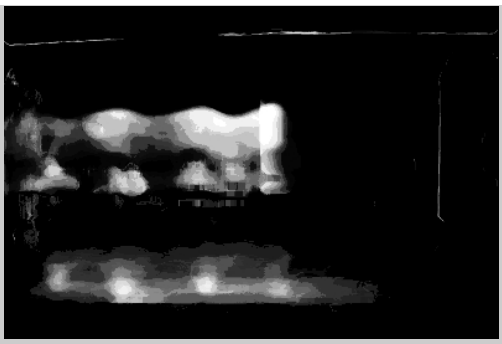
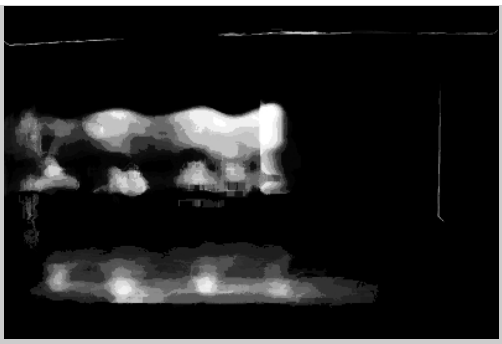
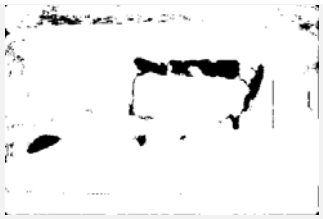
In the last set of results, it is thought that some eventual change of luminance disturbed the detection process.

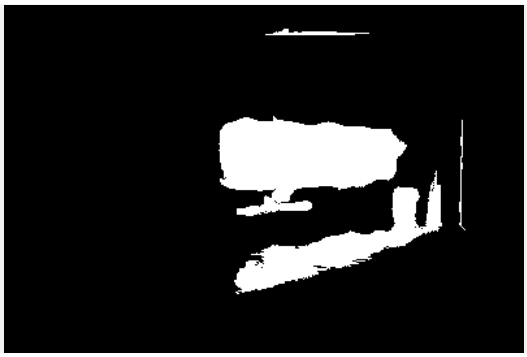
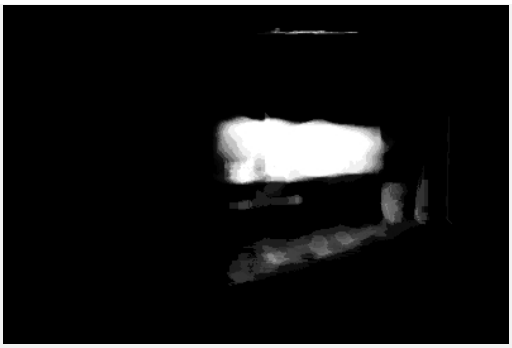
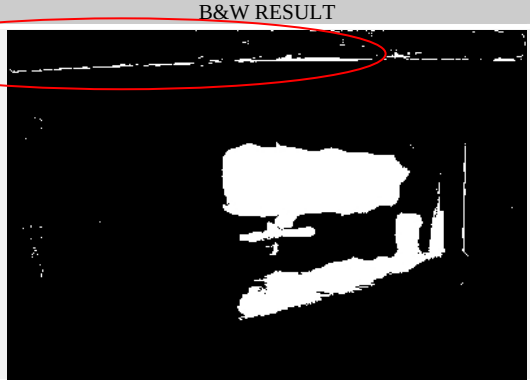
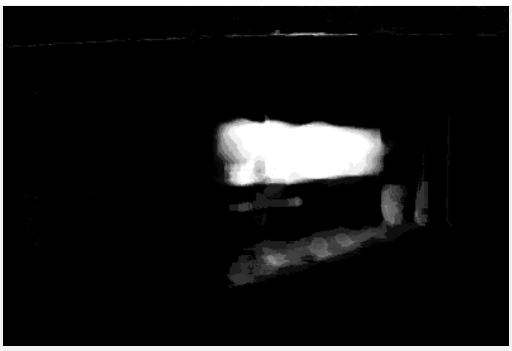
Shutter	**OUTDOOR2** Night		
2.5’’	ORTHOGONAL(B	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
	DIFFERENCE IMAGE			

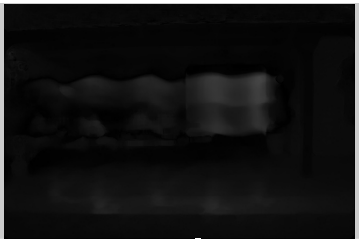
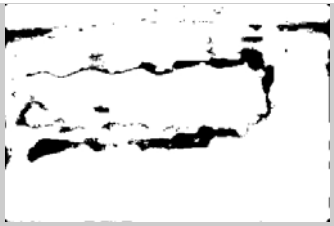
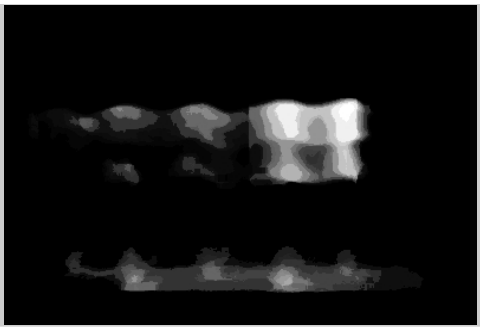
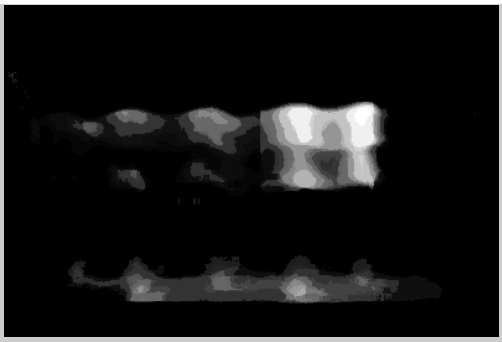
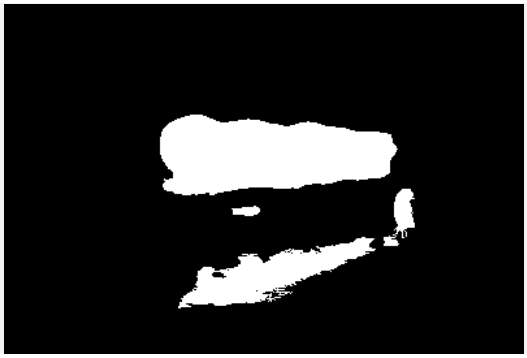
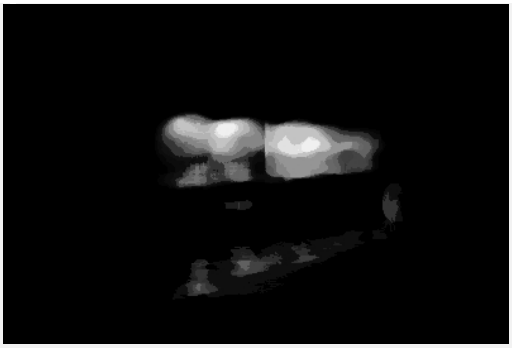

B&W RESULT
GRAY-SCALE RESULT
MEAN CORRECTION1
DIAGONAL(C)
MOTION IMAGE
DIFFERENCE (GRAY-SCALE)
B&W DIFFERENCE
DIFFERENCE IMAGE
B&W RESULT
GRAY-SCALE RESULT
MEAN CORRECTION1

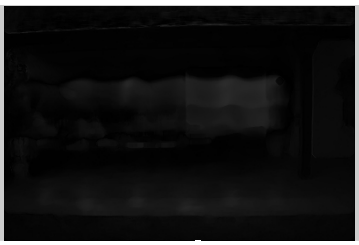
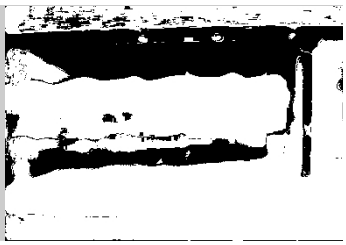
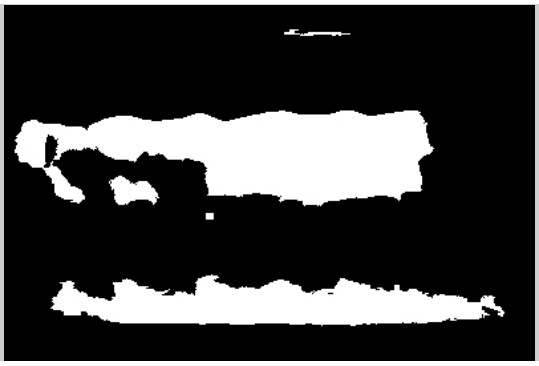
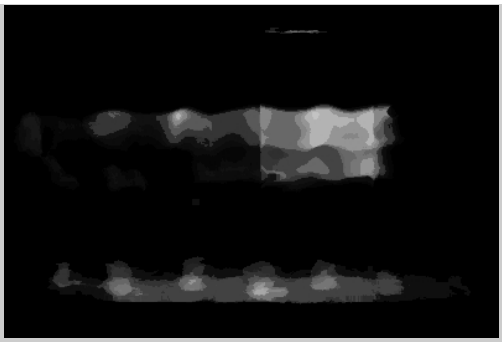
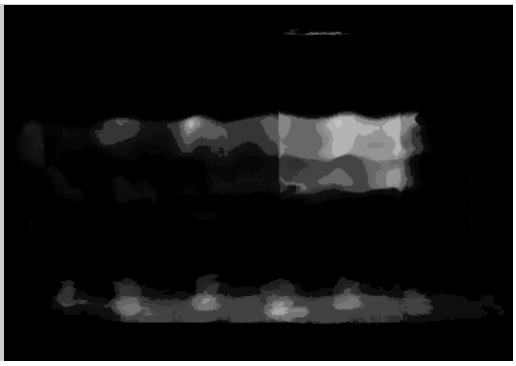
Shutter	OUTDOOR2 Night			
3’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

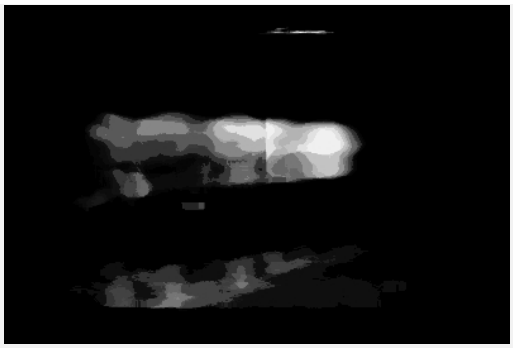
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

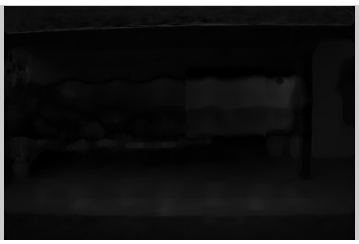
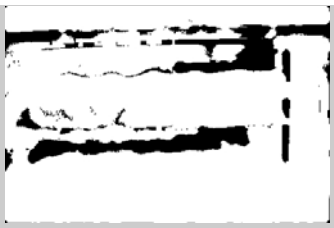
Shutter	OUTDOOR2 Night				
4’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

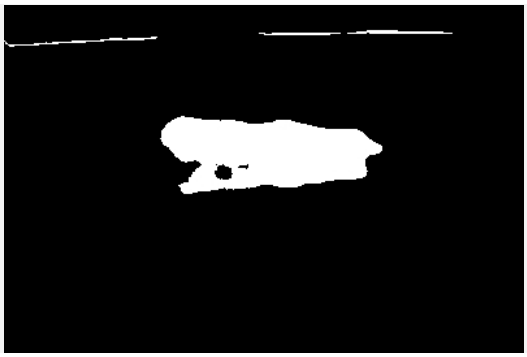
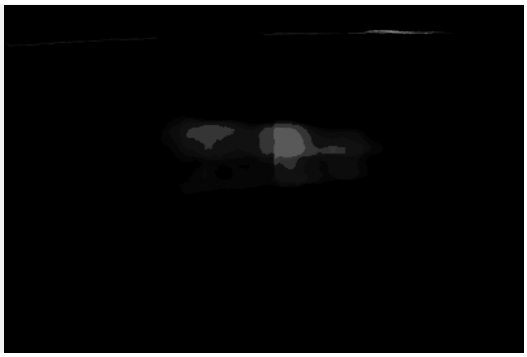
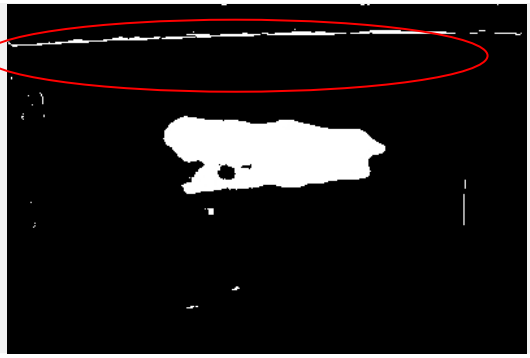
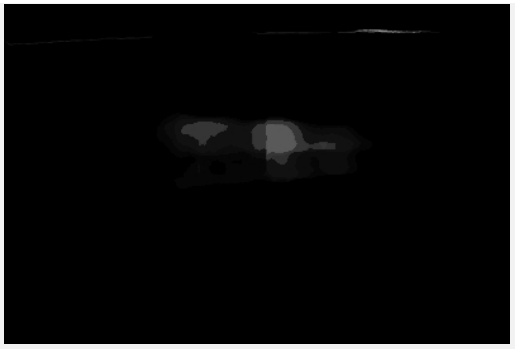
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
		MEDIAN CORRECTION1	B&W RESULT 	GRAY-SCALE RESULT 

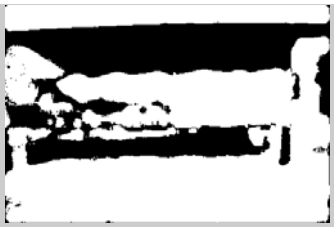
Shutter			OUTDOOR2 Night		
5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
			B&W RESULT	GRAY-SCALE RESULT	
		MEDIAN CORRECTION1			
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

Shutter	OUTDOOR2 Night			
6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
			B&W RESULT	GRAY-SCALE RESULT
		MEDIAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			

		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

Shutter	OUTDOOR2 Night			
8’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				
		DIFFERENCE IMAGE	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
					

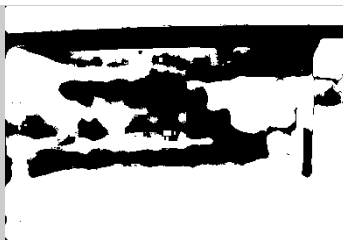
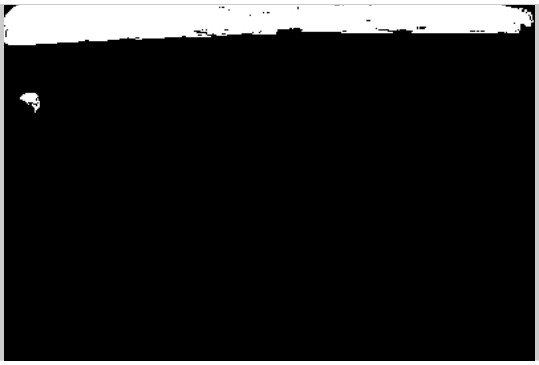
	DDIAGONAL(C)	**MEAN CORRECTION1**	**B&W RESULT**	**GRAY-SCALE RESULT**
				
		MEDIAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT
				

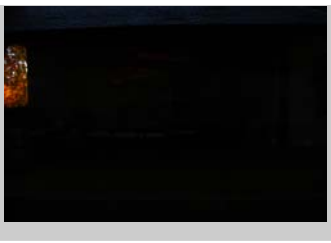
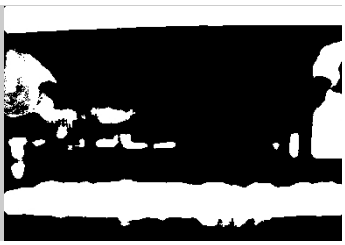
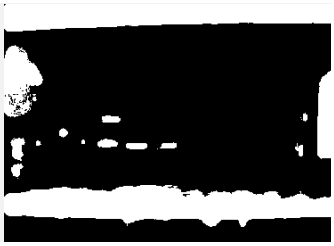
Shutter	**OUTDOOR2** Night		
10’’	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
ORTHOGONAL(B) DIFFERENCE IMAGE			
MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT	
			

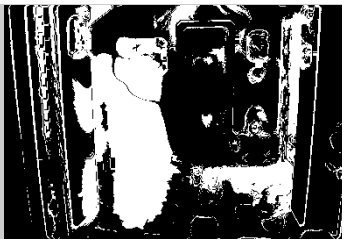
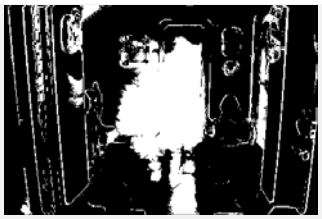
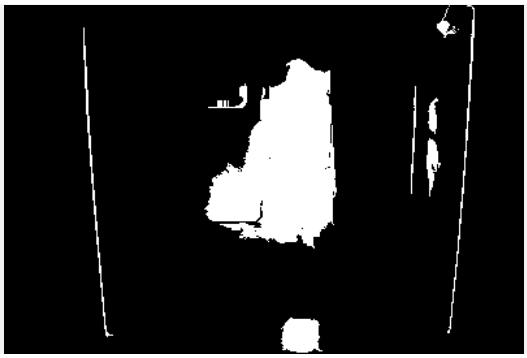
DIAGONAL(C)

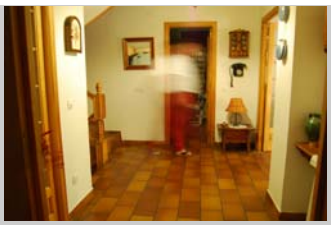
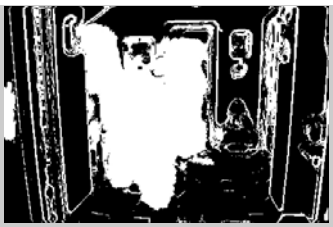
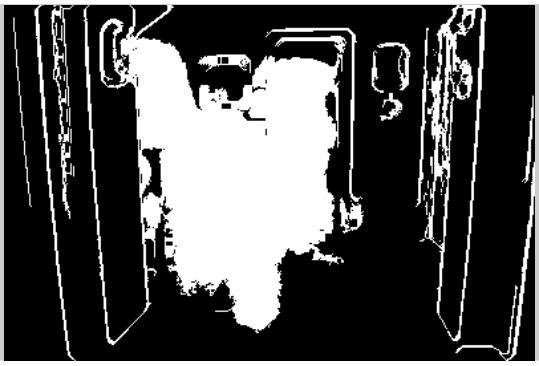
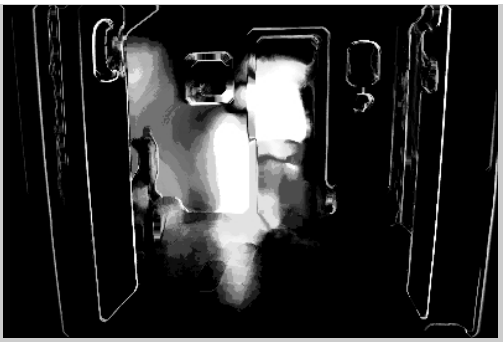
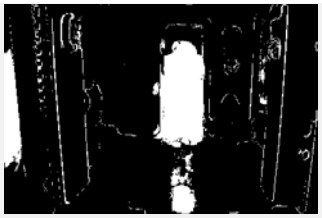
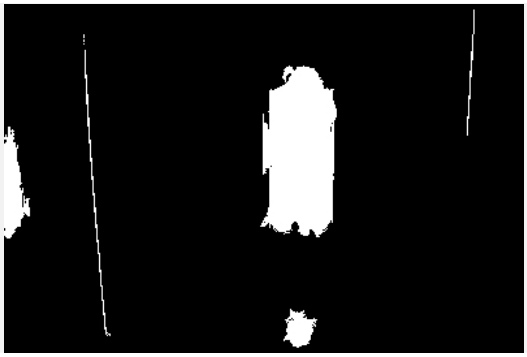
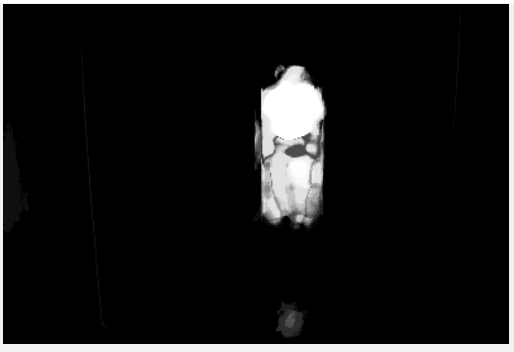
	MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
DIFFERENCE IMAGE			

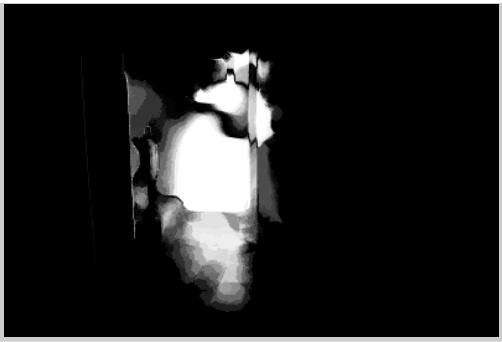
	B&W RESULT	GRAY-SCALE RESULT
MEAN CORRECTION1		

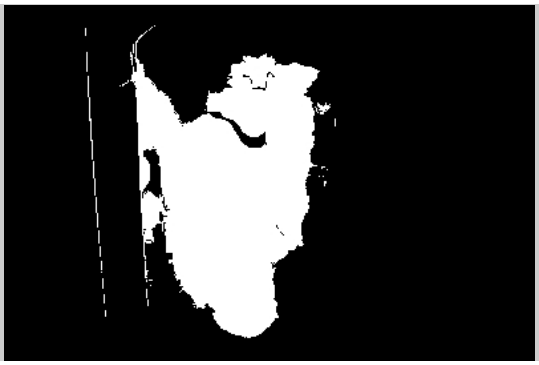
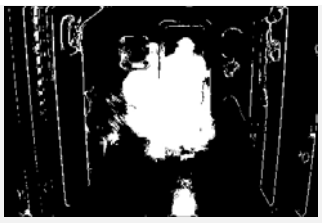
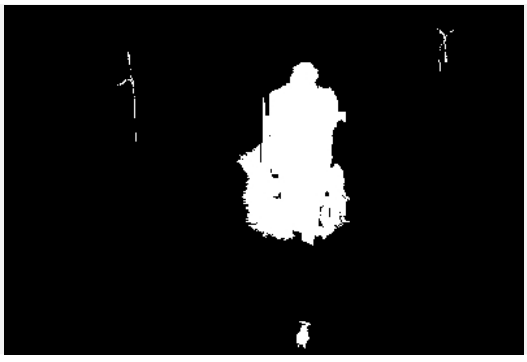
Shutter			OUTDOOR2 Night		
15''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT	
					
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT	GRAY-SCALE RESULT	
					

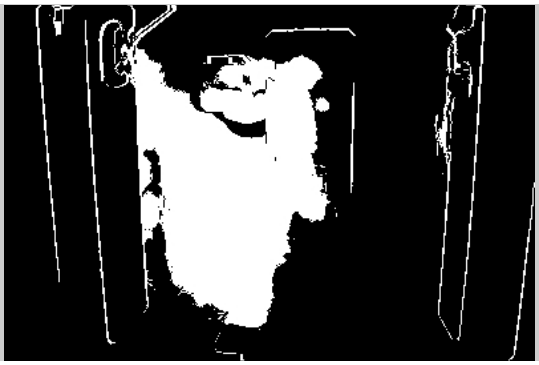
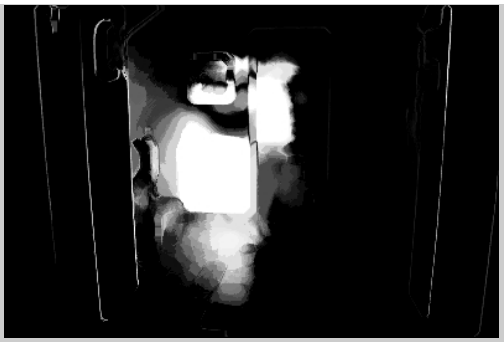
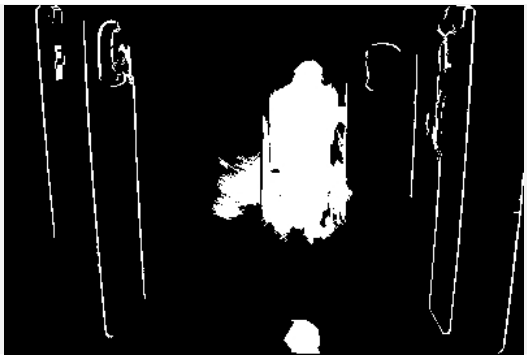
Shutter	OUTDOOR2 Night			
20''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	DIAGONAL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

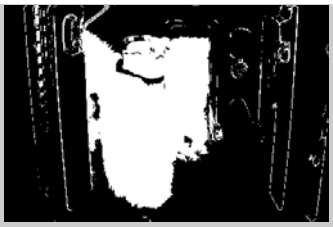
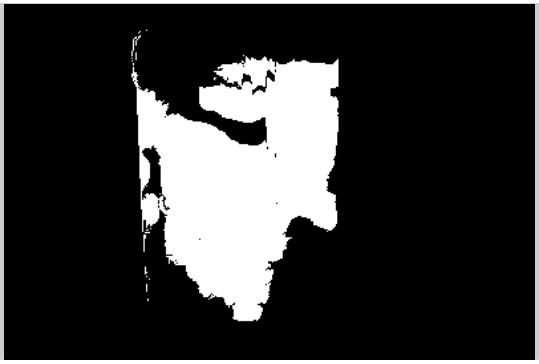
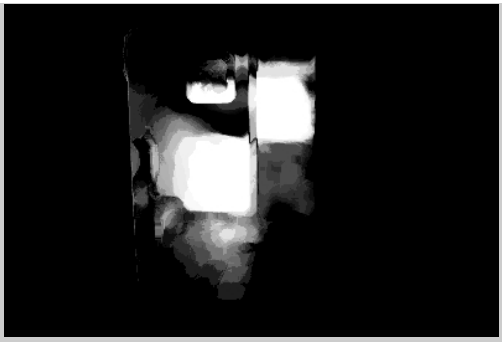
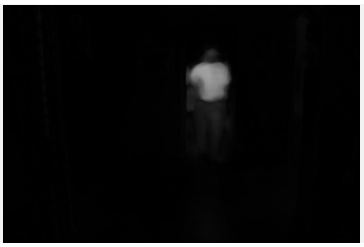
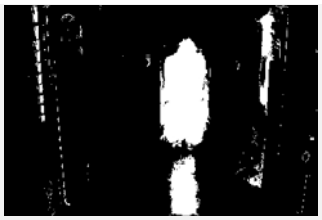
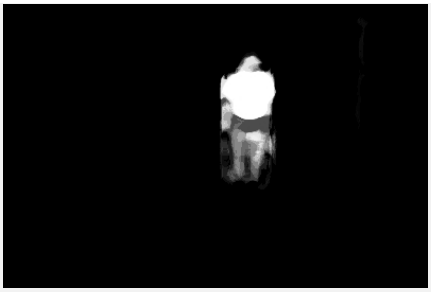
Shutter			INDOOR 1		
1''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					

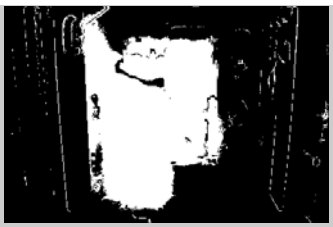
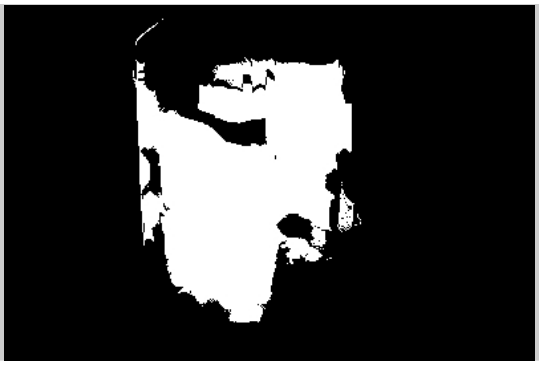
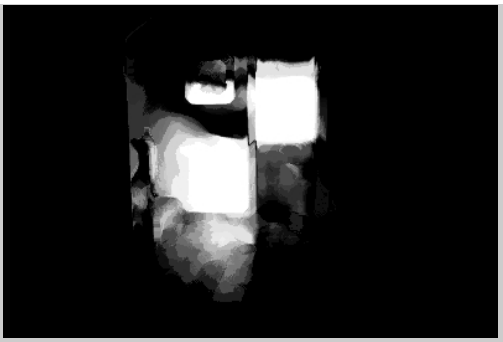
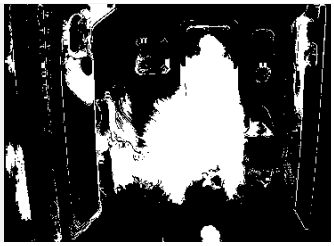
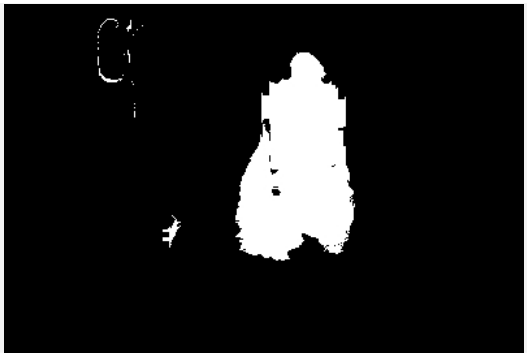
Shutter	INDOOR 1				
1.3''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			

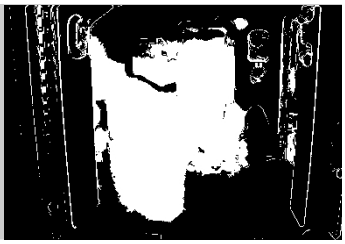
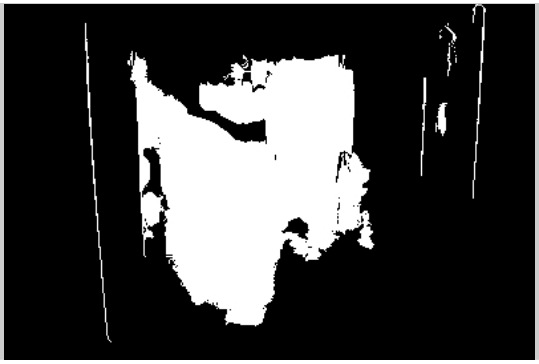
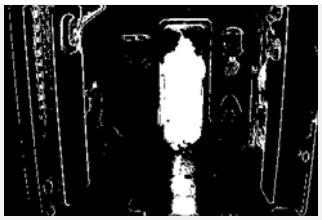
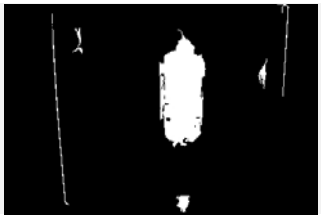
Shutter	INDOOR 1				
1.6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			

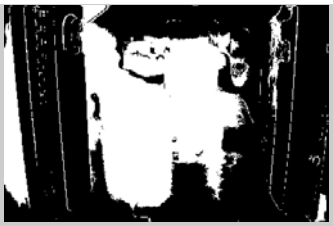
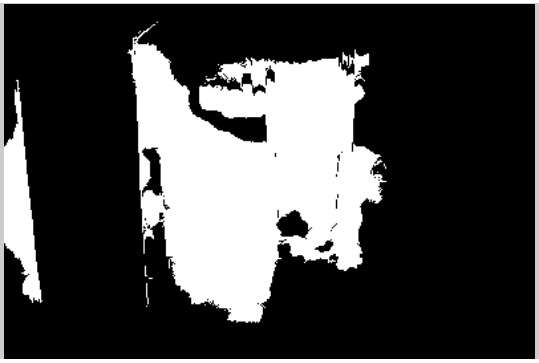
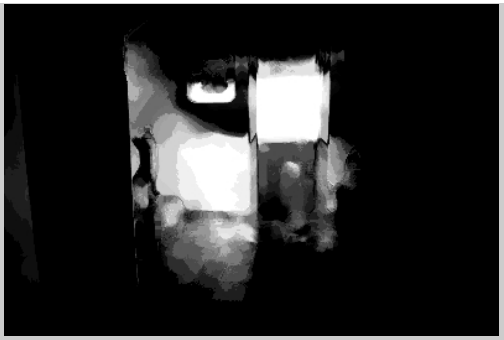
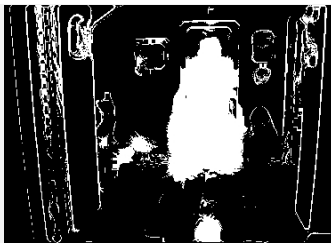
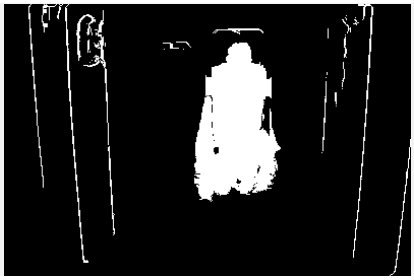
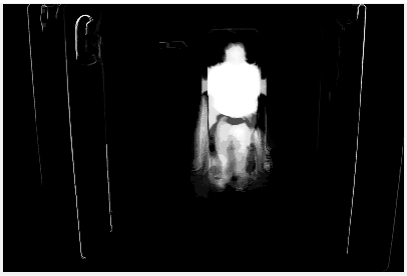
Shutter	INDOOR 1				
2’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

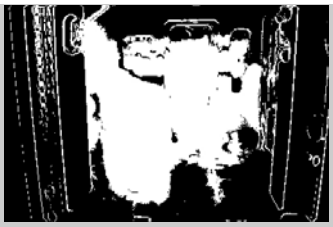
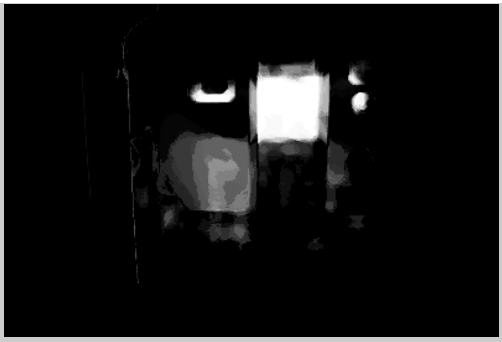
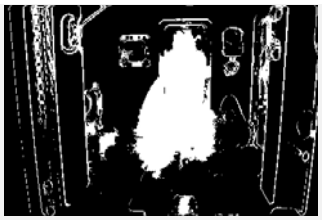
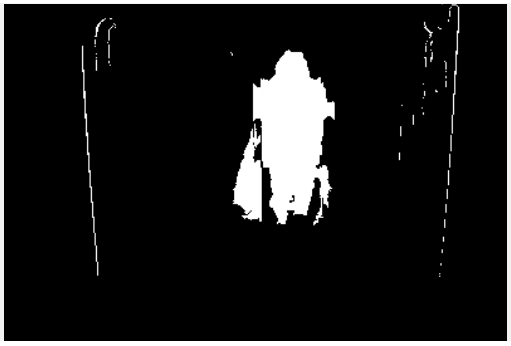
Shutter			INDOOR 1		
2.5''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

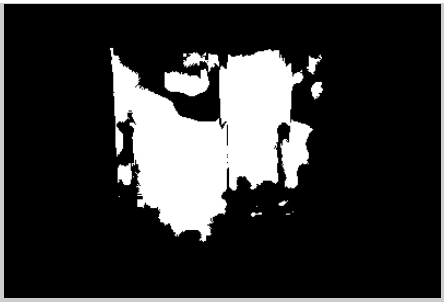
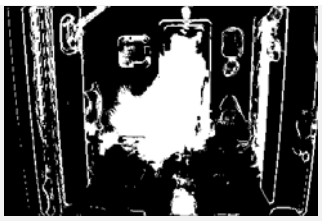
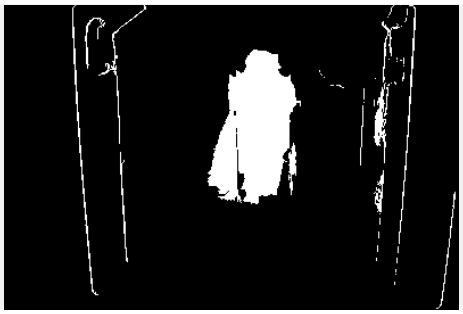
Shutter			INDOOR 1		
3''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
		MEAN CORRECTION1	B&W RESULT		GRAY-SCALE RESULT
					

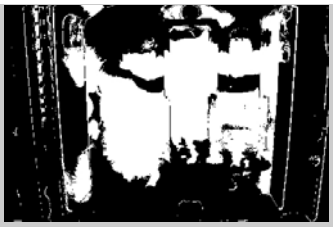
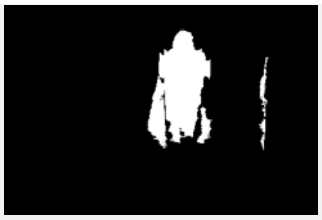
Shutter	INDOOR 1				
4''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			

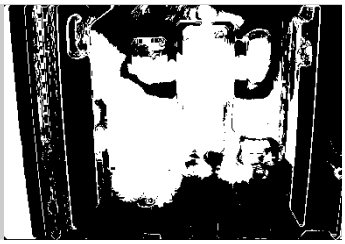
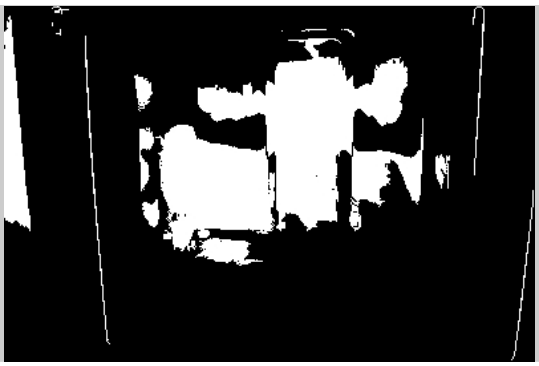
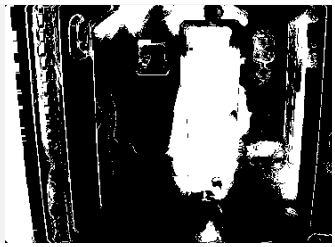
Shutter			INDOOR 1		
5’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

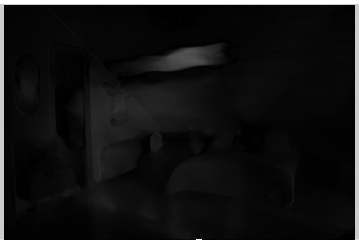
Shutter			INDOOR 1		
6''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

Shutter	INDOOR 1				
8’’	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT	
		MEAN CORRECTION1			

Shutter			INDOOR 1		
10''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			

Shutter	INDOOR 1			
15''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	PARALLEL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

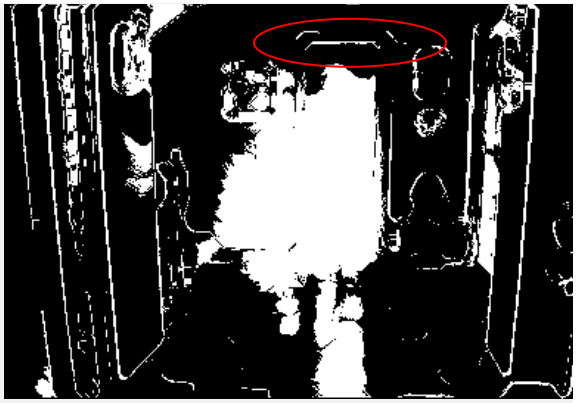
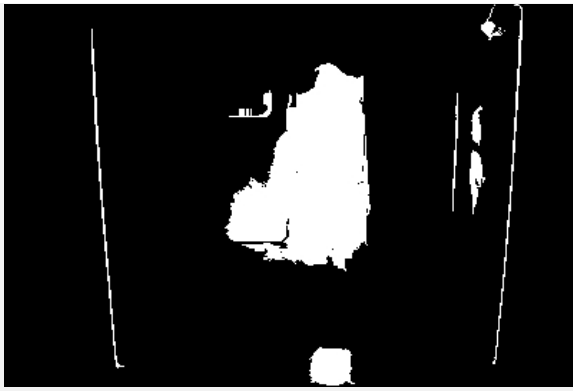
Shutter	INDOOR 1			
20''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		
	PARALLELL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT	GRAY-SCALE RESULT
		MEAN CORRECTION1		

Shutter	INDOOR 2				
2''	ORTHOGONAL(B)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			
	PARALLELL(C)		MOTION IMAGE	DIFFERENCE (GRAY-SCALE)	B&W DIFFERENCE
		DIFFERENCE IMAGE			
			B&W RESULT		GRAY-SCALE RESULT
		MEAN CORRECTION1			

6.3.2. Hybrid median filter vs Median Filter

Here, several examples of the hybrid median filter can be observed and also the comparison with respect to the results obtained by applying the standard median filter

to the same image. The size of the kernel is the same for both methods. The employed method is the "Mean Correction1"*(see 4.2.4.1.1).*

Shutter 1''	**INDOOR 1**
	PARALLEL
	MOTION IMAGE
DIFFERENCE IMAGE	
IINITIAL B&W DIFFERENCE IMAGES	**INITIAL B&W DIFFERENCE IMAGE (MEDIAN FILTER)** 
	INITIAL B&W DIFFERENCE IMAGE (HYBRID MEDIAN FILTER) 
B&W RESULT	**B&W RESULT (MEDIAN FILTER)** 
	B&W RESULT (HYBRID MEDIIAN FILTER) 

	GRAY-SCALE RESULT AFTER MEAN CORRECTION1	MEDIAN FILTER
		
		HYBRID MEDIAN FILTER
		

In this example, it can be observed how **the use of hybrid median filters performs a better edge preservation and provide less blur and more detail** than standard median filters. In the gray-scale image obtained by using the hybrid median filter, the head of the intruder is perfectly visible and detected, and even his hair can be seen. Besides, although the size of the kernels is the same for both samples, hybrid median filter detects a higher quantity of scenario features in rest, and consequently should not be detected, such as, wall's corners or space between floor tiles.

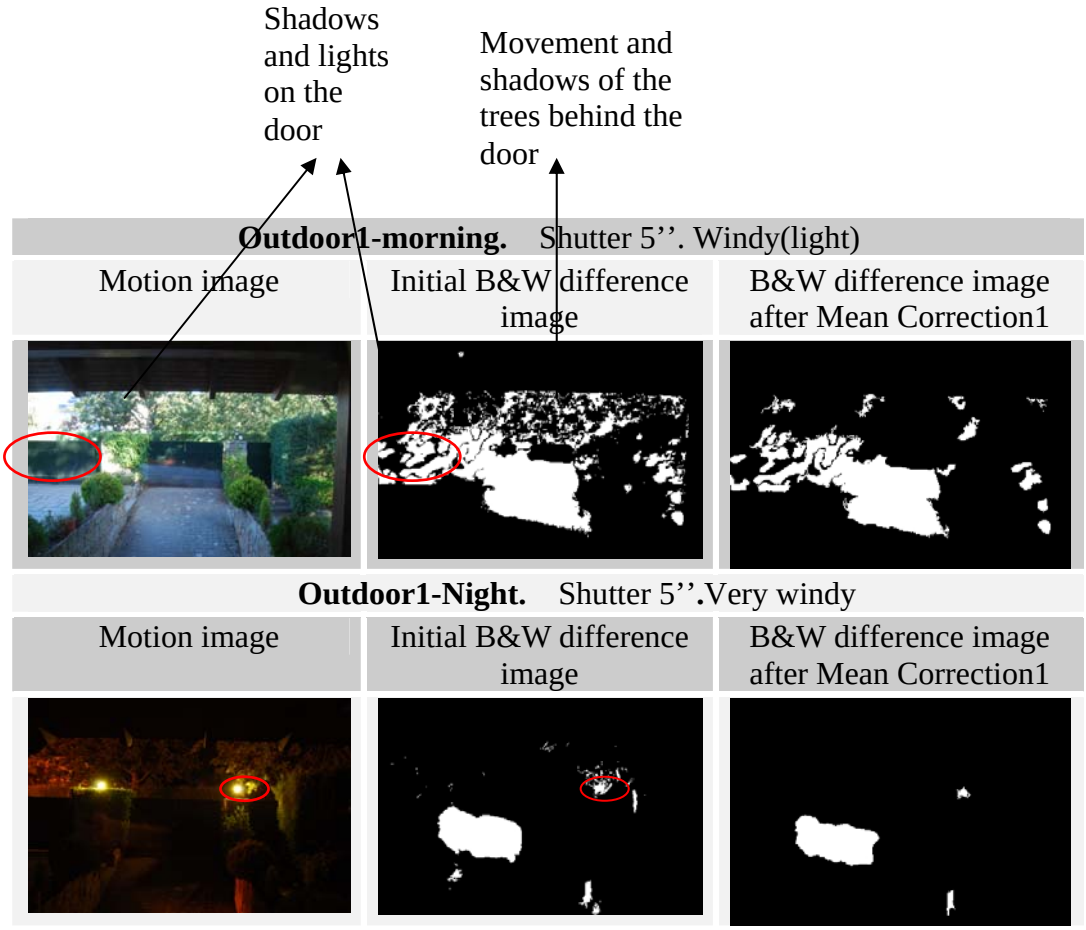
7. OBSERVATIONS

7.1. INFLUENCE OF SHADOWS

7.1.1. Influence of shadows formation and its relationship with the kind of scenario. Capability of the program to reduce shadows

7.1.1.1. Influence of shadows of "old" objects in movement.

This is the case of the **shadows created by the branches** of the trees moved by **wind.** Video-surveillance using images from **outdoor** scenarios are very sensitive to this kind of shadows, and although the approaches specified in paragraph *4.2.4.1.and 4.2.4.2.* will try to eliminate great part of the areas in the difference image, due to the movements of objects constituting the scenario, some of the shadows created while the objects are in movement will remain in the image, even after being processed. **So, the use of video-surveillance is much more suitable when used at night or indoor scenarios, because shadows do not interfere in the activity detection process.**
In the next example, two images of the same scenario are showed, the first one taken at the morning, and the second one, at night. Both images were taken using the same shutter speed: .



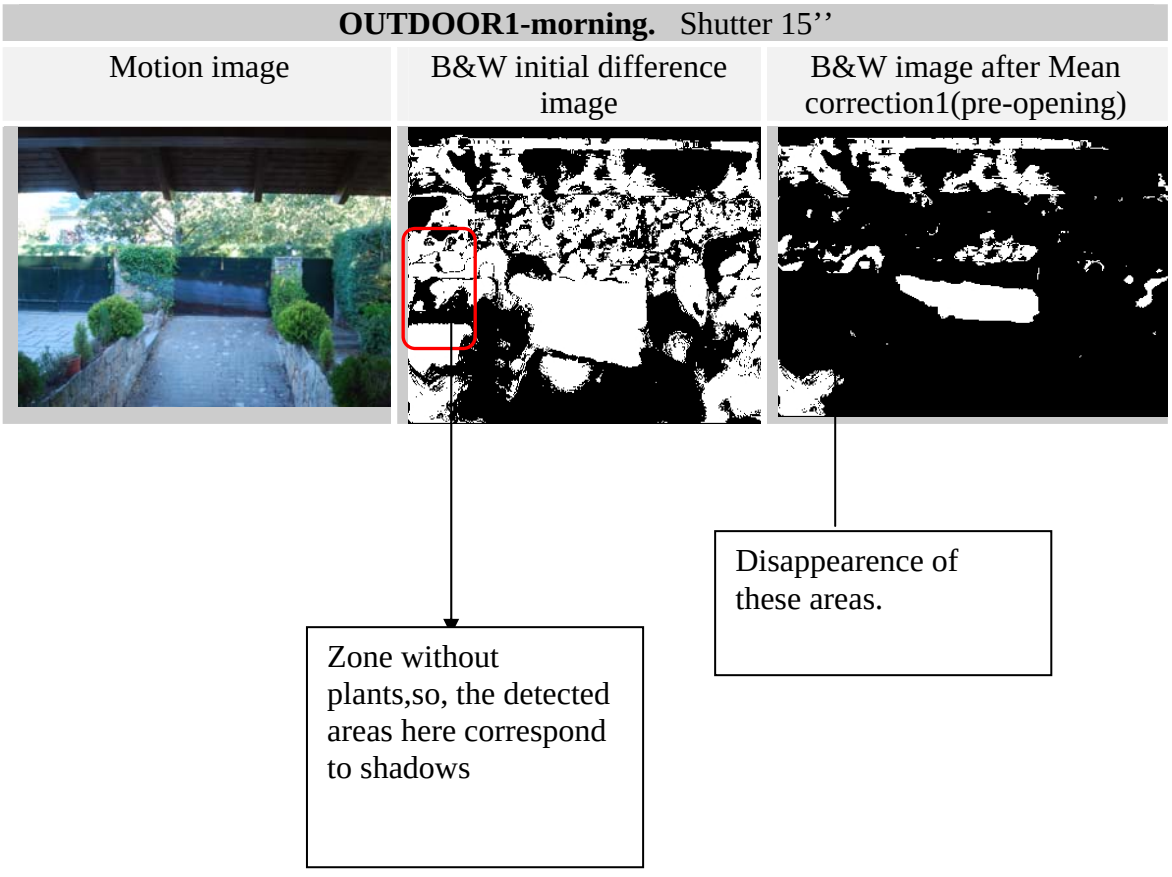
Movement of branches also cause the creation of new lighted zones, because leafs while moving let the light enters between them. Because of that, this kind of zones will not be removed during the processing, because they are considered to the program as part of an intruder.

When making a comparison between the initial B&W difference images from night and morning hours can be observed that **in the night image only a few areas which do not correspond to the intruder are detected, despite of the higher windy conditions corresponding to this image.** Furthermore, in the night image, the greatest one of this non-intruder areas correspond to the movement of the nearest branch to the lamp, and consequently, this zone produces shadows and new-lighted zones on the image.

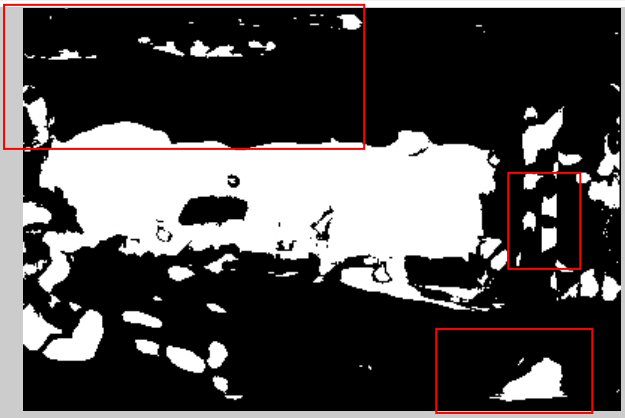
Besides, the highest the shutter speed, the greatest the sensitivity to detect activity corresponding to movement of branches with wind.

Thus, when using long exposure-surveillance the most suitable shutter speeds are those between 1'' and 4''.

Surprisingly, the four programs explained in paragraph *4*, (previously to performing the opening process), beyond its initial purpose of removing the detected areas which correspond to movement of branches ("old" object), also decrease the areas of shadows/lights created by movement of trees.



OUTDOOR1-morning. Shutter 15''

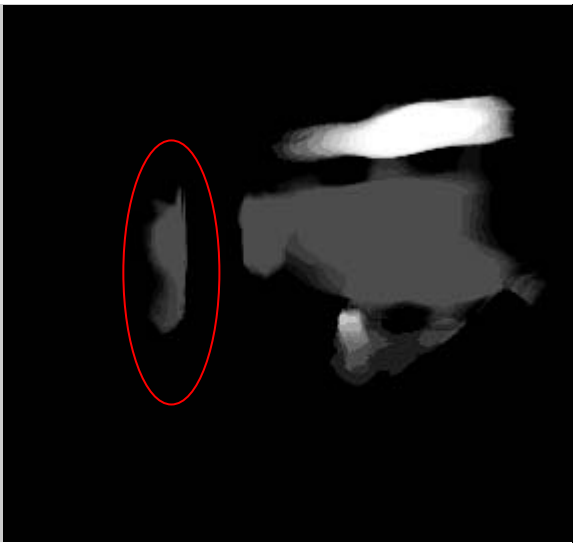
Motion image	B&W initial difference image
	
	B&W image after Mean correction1(pre-opening)
	

Although in this example, the influence of shadow removal is smaller, it can be observed how some particular areas are reduced after the treatment.

7.1.2. Improvement of Motion Detection by suppressing the step referred to the absolute value of the difference.

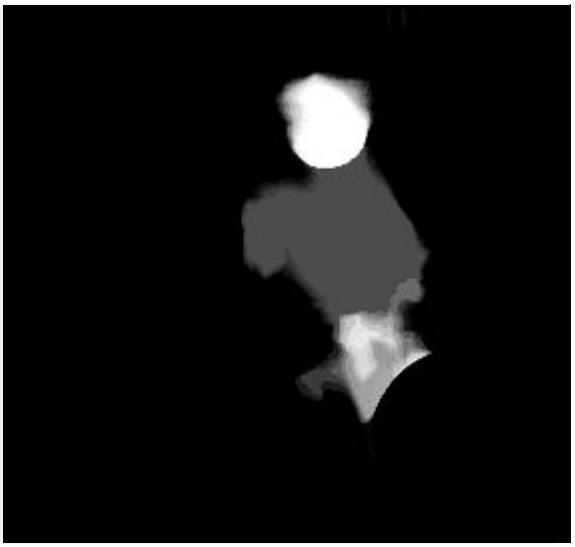
Usually, the main steps followed in order to achieve the motion detection are:
-performing the difference of two consecutive images and theoretically, if some change has been produced on the scenario, it will appear in the difference image.
-computing the absolute value. This step is performed because we are not interested in the sign, positive or negative, of the change produced between the interval passed between the two instants in which the photographs has been taken, but only in the magnitude of the change.

Thus, computing the absolute value provides more detail on the figures which appears in the difference image. But, when processing images in which the shadows of the element to detect disturb the detection process by incrementing considerably the intruder's area, it has been observed that suppressing the absolute value step, a more fitted detection takes place.

INDOOR 2- Shutter 2’’-Orthogonal	
Motion Image	
	
Final Result (gray-scale) -Computing the absolute value to the difference image	Final Result (gray-scale)- Without absolute value to the difference image
	
	This area corresponds to the seconds in which the intruder started to walk and his speed was lower than in the rest of the movement

PARALLEL

Final Result (gray-scale) -Computing the absolute value to the difference image	Final Result (gray-scale)- Without absolute value to the difference image

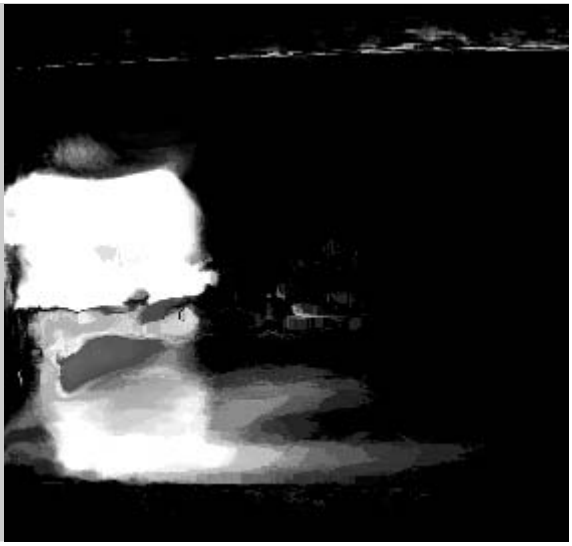


In the right image is more easily recognized the intruder than in the left image, because its shadow is eliminated if the absolute value is omitted.

Another example is presented here:

OUTDOOR2-Night- Shutter 1’’-Orthogonal

Motion Image

Final Result (gray-scale) -Computing the absolute value to the difference image	Final Result (gray-scale)- Without absolute value to the difference image
	
	It can be observed that, although part of the information is removed, the program eliminates the shadow and the purpose of detecting activity is met.

7.2. INFLUENCE OF COLOUR OF CLOTHES IN ACTIVITY DETECTION

In Indoor backgrounds the detection using dark clothes was satisfactory also, although the intensity of movements orthogonal to the camera axis belonged to a higher magnitude when the intruder wore pale clothes. The same happened in orthogonal movements performed in outdoor places at morning hours, i.e., the area of the intruder is highlighted with more intensity in the cases in which the intruder wore white clothes. Besides of this difference in the highlighted of the motion's intensity, in this scenario the intruder's area detected decreased in comparison with the area detected when wearing light clothes.

7.3.INFLUENCE OF SHUTTER SPEED ON ACTIVITY DETECTION

In the great part of the movements and shutters analyzed, the detection results correct.

In general, when analyzing the different movements on the scenarios, both types, orthogonal, parallel or diagonal to the camera's axis produce a correct detection. Logically, in orthogonal and diagonal movements the detected area was bigger than in parallel movements.

When studying the effects of the different outdoor scenario's lights concerning the moment of taking the photography, in the OUTDOOR1 scenario the area of intruder detected decreases in night series with respect to the morning series. In this series the best behaviours of the program turned out to be those from 1'' until 3''. Beyond these shutter speeds, the influence of shadows disturbs the intruder's detection.

In the OUTDOOR2 scenario, in the night series, a great change of luminance took place during the time while taking the images, because the series was took in the twilight. Until 6'' the identifications are perfect and also much better than those of the morning series. Because of the great changes of luminance during the twilight, the images corresponding to 15'' and 20'' do not present any area corresponding to the intruder and, instead, the roof is totally detected (erroneously). Instead, the use of these specific shutter speed did not disturb the motion identification in **OUTDOOR1. So that, it is believed that in NIGHT OUTDOOR scenarios, when using long exposures (10'',15'',20''…) the presence of an artificial source of light, such as streetlights or lamps becomes compulsory, although placing them next to trees or plants may disturb the detection process and to include shadows produced during the movement of branches.**

In indoor scenarios, any shutter speed produces a satisfactory result. However, movements orthogonal to the axis produce more precise and more recognizable areas than orthogonal ones.

7.4. DETECTED AREA’S REDUCTION AFTER THE PROCESSING

It has been noticed that for exposures higher then 10’’ , sometimes the intruder’s area is reduced considerably after the treatments described in 4.2.4.1or 4.2.4.2, and in some cases this area, which appeared totally visible and it was completely recognizable because it constituted the largest area in the difference image, after being processed almost disappears or is fragmented in small parts .

8. ANOTHER ATTEMPS

8.1. ATTEMPS FOR COMPENSATE INFLUENCE OF LUMINANCE CHANGES

8.1.1. Performing the mean of a set of background images and computing the difference image with respect to this difference image

It has been thought that this proposal could solve the eventual problems of little deviations of luminance, because tends to set, for each pixel, the more usual level of its intensities through the set of images. This is the method implemented in all the series of images presented in paragraph *6.3.*

8.1.2. An attempt to perform the difference image in the HSV space

In order to compensate the eventual changes of luminance which disturb the activity detection process by producing a great variation on the RGB intensity value of each pixel and provide false alarms and error in the detection of intruders, it has been thought to work on the HSI space. This colour space is independent of luminance, so that, the changes of luminance should not affect to the detection process. Unfortunately, it was impossible to achieve any successful result.
NOTE: (*Matlab works in HSV colour space)*

8.1.3. An attempt to perform the difference image in the NTSC space

As the last attempt failed, it was thought to work in the NTSC space. The attempt consisted in assigning to the motion image the luminance of the background image. Thus, theoretically, the luminance is constant and changes of luminance should not be a problem on the scenario. But, even with this proposal, the difference image did not show what it was expected.

8.1.4. Enhancement of multispectral images. Intensities quotient

The program developed specifically to produce a compensation of intensities in order to make less sensitive the activity detection process to luminance variations, is based on the quotient of images. Given a set of *I* images of the same scene, and calling to each one of them as u_i , $i=1,2,\ldots I$, the quotient image between two images of the set it is defined as :

$Ri,j = (u_i / u_j)\ i \neq j$

Thus, a set of quotient images are obtained. These set of quotient images relate every image of the initial set by pairs. Then, by visual inspection, from all of the images of quotient set, the image that better represents the scenario features is selected.

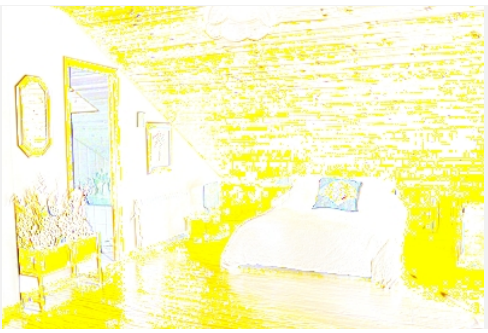
The program is based on the previous description of quotient images. The main idea is, given a set of background images, **computing the quotient image of each pair of images of the set, and subsequently, selecting the image which best represents the background features**. Later, for each canal of the selected image, the **median of their canal intensities** is computed, defining thus, **a correction factor**. Then the each canal of the motion image is divided, by the respective factor. The same process is repeated

for the average image (of the set of backgrounds), i.e. each canal of the average image is divided by its respective factor.

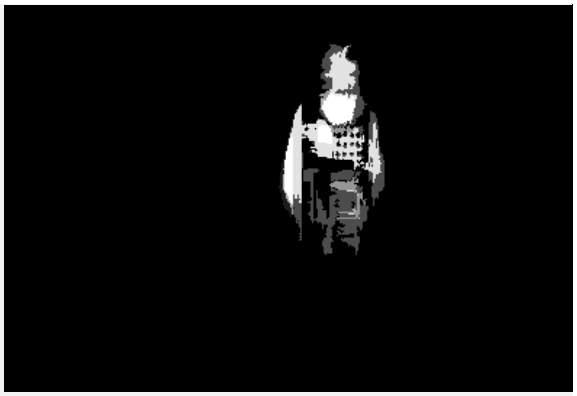
This program was tested on the series corresponding to INDOOR2 and the quotient image that better fitted to the background images resulted to be the first one, i.e., that which represents the quotient between the first and the second images of the set, and it was called R1.

Once computed these corrections on the images to be subtracted, i.e., the average image and the motion image, the rest of the steps of the program are similar to those explained in paragraph *4*, with the exception of the next fact: after obtaining the difference image, a threshold is applied. The type of correction selected is *Mean Correction1*. The kind of the threshold applied is **the Otsu's Method**.

In the next figure, a comparison between the standard *Mean Correction1 Method* explained previously in and the combined variation which use the multispectral quotient method, is showed:

Motion Image-Shutter 2''- Parallel	**Quotient Image**
	
	Gray-scale Result
	

It increases significantly the sharpness of the difference image. It can be observed in the next example.

Motion Image-Shutter 20’’- Parallel-Dark Clothes	
	
Gray-scale result Mean Correction1	**Gray-scale result MultispectralQuotient**
	
	Observe that in this method some scenario features which are placed behind the intruder appears as forming part of the intruder (it can be also seen in the previous example of INDOOR2)

8.1.5. Enhancement of multispectral images. Logarithm of the intensities quotient

A variant to the last method consists in applying the logarithm to quotients of images. This suppose an advantage, because if the denominator of some quotient becomes 0, the result will be huge using last method and the dynamic range will be also huge, but taking logarithms suppose a better visualization of that image because of a compression of the dynamic range.

The algorithm is based on the next expression:
$Ri,j = log[(u_i / u_j)]$ $i \neq j$

Motion Image-Shutter 2’’- Parallel	**Log(Quotient) Image**
	
	Gray-scale Result
	

However, this method had no success in identifying intruders.

8.2. THRESHOLDING THE DIFFERENCE IMAGE BY THE MAD/MED METHOD

This method was extracted from the paper “*Image difference threshold strategies and shadow detection”* described in bibliography. It is based on searching an efficient threshold using robust statistic.
The steps are:
1)Computing the absolute value of the difference image $D=abs(M-B)$,where M is the motion image and B is the background image.
2)Calculating the median $MED= median(D)$
3)Calculating the median absolute deviation $MAD= median_{x,y \in I} (abs(D_{x,y} -MED))$
4)Considering that less than half the image correspond to motion areas, the median should correspond to usual noise values, and consequently, a suitable threshold is $T=MED+3\times1.4826\times MAD$, where 1.4826 correspond to the normalization factor with respect to a Gaussian distribution.

However, the results obtained after processing the images with this technique did not show important enhancements.

8.3. AUTOMATIC THRESHOLD OBTAINED BY PERFORMING THE 0.75 QUARTILE OF THE STANDARD DEVIATIONS THROUGH A SET OF BACKGROUND IMAGES

Firstly, given a set of background images, the standard deviation of each pixel of each canal along the set is computed. The result of this process is a matrix. Then the median filter is applied to this matrix and later, the 0.75 quartile of the intensities inherent to each canal is calculated and these three values are selected as each respective canal threshold. This method of thresholding presented satisfactory results.

9. CONCLUSIONS

In this project, several techniques in order to enhance the activity detection are developed.

Mainly, four methods presented in order to eliminate the activation of a false alarm due to the motion of objects which belong to the scenario. Two of them are based on the comparison of mean/median intensities in the background and in the motion image. The pixels whose intensities must be compared are those constituting each area of the difference image. Besides, the comparisons are referred to several threshold values. The conclusions of the results of these four approaches are presented here:

- **All the methods** (Mean Correction1, Mean Correcion2, Median Correcion1, Median Correction2) **presented significative results** when trying to eliminate alarms coming from movement of trees and preserving the alarm by intruder. The results of all of them are very similar, although light deviations happen in Mean and Median Corrections1.

- In some cases Median Correction1 tends to preserve better the contour of the intruder than Mean Correction1, and in general, tends to eliminate eventual areas which do not belong to the intruder, providing a "cleaner" identification. Anyway, both methods present good results.

- **In outdoor scenarios, for the longest exposures, when processing the images with Mean/Median Correction1 (or 2) part of the tail of the intruder in motion disappears, and consequently the area of the intruder is smaller than the respective one presented in the initial difference image**

. **Shadows and new lighted zones appearing during the movement of trees may influence negatively the process of removal of areas belonging to movement of "old" objects, because they are considered by the program as "new" object on the guarded zone**. Because of this reason, in night scenarios, if trees or plants are placed close to a source of light such as streetlights it may produce false alarms in the detection of the intruder

-When working in **outdoor scenarios**, as **shadows are less probable in night scenarios**, it is **better** to work in **night** conditions when using **long exposure images**, but always taking care of the fact presented at the previous point and having into account that **for longer exposures than 10'' a source of light must be placed because, on the contrary, no intruders will be detected**. It must be noted the superiority of working at night conditions because **even in highly windy nights the results were better than at morning hours of days without wind.** However, **working at night decreases (non-significantly) the intruder's area detected.**

-In general, for all the shutter speeds and scenarios studied, the motion identification was satisfactory except in the night scenario where any source of light was not present.

-In scenarios where the **shadow of the intruder may influence negatively** in the activity detection process it is convenient to **not performing the absolute value** to the

difference of the images, but only the difference. However, **a lost of detail** on the intruder will take place.

- Hybrid median filtering provides better edge preservations than standard median filters, but a greater quantity of scenario features in rest are detected and consequently, standard median filters provide a cleaner image.

-For compensating the eventual changes of luminance **that disturb the detection the best method is** the quotient of multispectral images**.**
It **increases significantly the sharpness** of the difference image and some objects placed behind the intruder appears as belonging to him

10. FUTURE WORKS

The worst problem found during the development of this project has been the **erroneous identification of shadows and new lighted zones appearing in outdoor scenarios as a consequence of movement of plants** ("old objects"), as areas belonging to an intruder on the scenario. This fact, generally appears in **windy days**, but anyway although light drafts happen, this elements appear and disturb the correct intruder detection. So this is a problem to be solved in future.

The proposals implemented in order to identify movement of objects already present on the background from those entering on the scenario are based on the comparison of the means/medians of intensities in the background and motion images with respect various selected thresholds. Another **attempts for achieving more effective comparison's threshold may be investigated in order to increment the percentage of removed areas belonging to "old" objects.**

Another line of work may be the **enhancement of the deblurring process in order to get more information about the intruder's features.** On the other hand, techniques for obtaining the field of velocities may be implemented, such as the ***optical flux method*.**

Besides, in order to enhance the detection of intruders with dark clothes, contrast enhancement techniques may be implemented, such as ***the Stadistics Scaling and the Inverse Contrast Ratio,*** which provide an image in which weak edges or with low contrast become enhanced.

APPENDIX A

In this section, a list of the programs implemented during the project will be showed. They will be also explained in terms of their parameters.

NOTE. The outputs listed here, are referred to the written ones. Other figures are displayed while executing the different programs, such as the **boundaries extraction and holes extraction** in MotionDistinguishingMean1.

MotionDistinguishingMean1

MotionDistinguishingMean1*(folder_background,pre_str_backgnd,image1,total_images,folder_motion,pre_str_motion,image_motion,format,folder_results,scenario,detail,type_median)*

This function isolate the motion of objects which were not already present on the scenario and rejects the movement of objects which belongs to the background. The method employed is Mean Correction1*(see 4.2.4.1.1.)*, i.e. compares the MEANS of the intensities in the background and in the motion images. The comparison is established by performing the difference between the means of intensities in the background and in the motion image and later, it performs the comparison of this difference with a threshold set as a function of the MEAN of the standard deviations of the intensities in the background image.

The background image selected to perform the difference with respect to the motion image, is the average image of a series of background images contained in folder_background.

Inputs:

folder_background: string specifying the whole direction of the folder containing the set of images of background
NOTE: The number of the images on folder_backgnd must be correlative

pre_str_backgnd: string containing the characters previous to the number of the background images. It also includes the number of zeros previous to the first integer different from zero. For example, if the image it's called _R1E0232.png, the pre_str_backgnd variable should be pre_str_backgnd='_R1E0' considering the photo number equal to 232, so the variable image1 should be image1=232

image1: integer describing the number of the (first) background image in the set of background images contained in folder_background

total_images: integer referred to the total number of images in the set of backgroud images

folder_motion: string specifying the whole direction of the folder containing image_motion

pre_str_motion: string containing the characters previous to the number of motion_image. (Analogous to pre_str_backgnd)

image_motion: integer describing the motion image's number. (Analogous to image1

format: string containing the extension of the images.
NOTE: Do not include the character '.'
Example: format could take a value like:
format='png' or format='tif'

folder_results: whole direction of the folder created in order to include the results that the program will elaborate. The use of this folder is, mainly, to classify the different results elaborated from the different programs.

scenario: integer with values:
1 if STANDARD SCENARIO
In this case the absolute value to the difference of the background and motion images is calculated, achieving a high detail, because we are not interested in the sign of the values in the difference image but only in their magnitude.
2 if SCENARIO is propitious to development of intruder's shadows which may interfere in the identification process. In this case the absolute value of the difference of the background and motion images is not calculated, but only the difference.

detail: It is a flag specifying the level of the threshold used when converting the RGB difference image into a BLACK AND WHITE image. So, the smaller the threshold the more detail will be obtained in the B&W difference image.
integer with values:
0 if we do not want a detailed difference image. The level of the threshold is set at 0.1
1 if we need a detailed difference image. The level of the threshold is set at 0.02

type_median: integer with values
1 if median filter
2 if hybrid median filter

Outputs:

1) average(backgrounds):The average image resulting from performing the means for each pixel of their intensities through the set of background images.

2) The difference image, resulting from subtracting the average image to the motion image. Depending of the value of the parameter *scenario* it may also be

the result of applying the absolute value to the previous difference image. Three outputs are obtained from this difference image:

Difference(RGB)_wrt_average_image The RGB difference image

Difference(gray)_wrt_average_image: The gray-scale difference image

INITIAL B&W DIFFERENCE IMAGE The B&W difference image

3) B&W DIFFERENCE IMAGE AFTER Mean Correction1: The image resulting from applying the Mean Correction1 processing but without applying the opening process.

4) Motion_Identification(Mean1)extreme: Final result of the program, after applying Mean Correction1, the opening process and a thresholding process referred only to the highest magnitudes of motion.

5) Motion_Identification(Mean1)graduate: Final result of the program as a gray-scale image, after applying the Mean Correction1 processing, the opening process and also the different thresholdings (establishing different levels for different magnitudes of motion)

6) Motion_Identification(Mean1)B&W: It is the last image passed to binary image.

7) CANNY_Motion_Identification(mean1)graduate: It is the result of applying the Canny edge detector to the image described in 5)

8) DEBLURRED IMAGE: Result of applying the Lucy-Richardson deconvolution to image described in 5)

Example of call function:

MotionDistinguishingMean1('C:\Users\sandra\Documents\MATLAB\INDOOR1\20\BACKGROUND(A)','DSC_0',281,7,'C:\Users\sandra\Documents\MATLAB\INDOOR1\20/ORTHOGONAL(B)','DSC_0',290,'jpg','C:\Users\sandra\Documents\MATLAB\INDOOR1\20\ORTHOGONAL(B)\resultsMEAN1',1,1,1)

MotionDistinguishingMedian1

This function has exactly the same inputs and outputs than MotionDistinguishingMean1 but adapted to the Median Correction1.*(see 4.2.4.2.1.)*

MotionDistinguishingMean2 *(see 4.2.4.1.2.)*
MotionDistinguishingMedian2*(see 4.2.4.2.2.)*

Both functions have the same input parameters and outputs than Motion DistinguishingMean1 with the exception of the Deblurring process, which in these functions are not performed.

hmf

hmf*(A,n)*

This function performs the Hybrid median filtering to the matrix A using a NxN kernel. B = HMF(A) uses N = 5 (default value).

Inputs:

A : it is the imput matrix. It can be a 2-D array or an RGB image. If A is an RGB image, hybrid median filtering is performed in the HSV colour space.

n : it is the size of the kernel

Notes:

1) N must be odd. If N is even then N is incremented by 1.

2) The Image Processing Toolbox is required.

3) If the function NANMEDIAN exists (Statistics Toolbox), NaN are treated as missing values and are ignored.

Example of call function: *hmf(motion_image, 5)*

MED

Performs the thresholding process described in paragraph *8.2*. Later, the method employed for removing motion of objects which were already present on the scenario previously to the entering of the indruter on the guarded zone, is the *Mean Correction 1*.

MED*(folder_background,pre_str_backgnd,image1,total_images,folder_motion,pre_str_motion,image_motion,format,folder_results)*

Inputs:

The inputs listed as parameters of MED are the same that those explained for *MotionDistinguishingMean1*.

Outputs: The outputs are the same than the *MeanDistinguishingMean1* ones.

Example of call function:

MED('C:\Users\sandra\Documents\MATLAB\INDOOR1\20\BACKGROUND(A)','DSC_0',281,7,'C:\Users\sandra\Documents\MATLAB\INDOOR1\20\ORTHOGONAL(B)','DSC_0',290,'jpg','C:\Useres\sandra\Documents\results')

MultispectralQuotient

MultispectralQuotient*(folder_background,pre_str_backgnd,image1,total_images,folder_motion,pre_str_motion,image_motion,format,folder_results,logar)*

It performs the *Mean Correction1* method, but previously, it uses the methods for compensating luminance by intensities quotient of multispectral images, described at paragraphs *8.1.4.* and *8.1.5.*

Input: The parameters used by *MulitspectralQuotient* are the same that those utilized in *Mean Correction1,* except the last one: *logar*, that it is specific for *MultispectralQuotient:*

logar: integer whose values are:

1 if it is only required the quotient of the images. The dynamic range can be high in the case some 0 is placed in the denominator. *(see 8.1.4.)*

2 if it is required the log (quotient) in order to reduce the dynamic range of the images *(see 8.1.5.)*

Example of call function:

MultispectralQuotient('C:\Users\sandra\Documents\MATLAB\INDOOR1\20\BACKGROUND(A)','DSC_0',281,7,'C:\Users\sandra\Documents\MATLAB\NIKON\INDOOR1\20/PARALLEL(C)','DSC_0',291,'jpg','C:\Users\sandra\Desktop/results',1).

YIQconversionLuminance

YIQconversionLuminance*(folder_background,pre_str_backgnd,image1,total_images,folder_motion,pre_str_motion,image_motion,format,folder_results)*

This program is referred to the approach described in 8.1.3.This function performs the Difference image from the motion image and the average image of a set of backgrounds which have been previously transformed into NTSC space. The luminance of the motion image is set equal to the background image in order to make constant the luminance of both images to be subtracted and thus, eliminating the influence of eventual changes of luminance in the environment. Besides, the Mean Correction1 method is used.

Inputs:

The parameters of this program have the same function than those explained in Mean Correction1.

Outputs:

The outputs of this program are the same than those explained in Mean Correction1, although the Canny Edge Detector and the Deblurring process are not used in this function.

Example of call function:

YIQconversionLuminance('C:\Users\sandra\Documents\MATLAB\INDOOR2\BACKGROUND(A)','DSC_0',434,3,'C:\Users\sandra\Documents\MATLAB\INDOOR2\ORTHOGONAL(B)','DSC_0',437,'jpg','C:\Users\sandra\Documents\results')

Linearfilter

linearfilter *(folder,expos,pre_str,num_image,format)*
This program was created in order to see the effect of two linear filters and compare them with the effect of the median filter, but, as predicted, the effect of this last filter enhanced the results with respect to the linear ones.
Inputs

folder: string containing the direction of the folder which contains subfolders corresponding to different time expositions. (The images corresponding to the same time expositions must be grouped in a single folder called like the number of seconds of expositions.

Example:The direction cointained in “folder” includes 4 subfolders corresponding to images of 1,3,5,7 seconds of expositions:
folder='C:/IMAGES' IMAGES contains the folders '1','3','5' and '7'.

expos: integer referred to the seconds of exposition

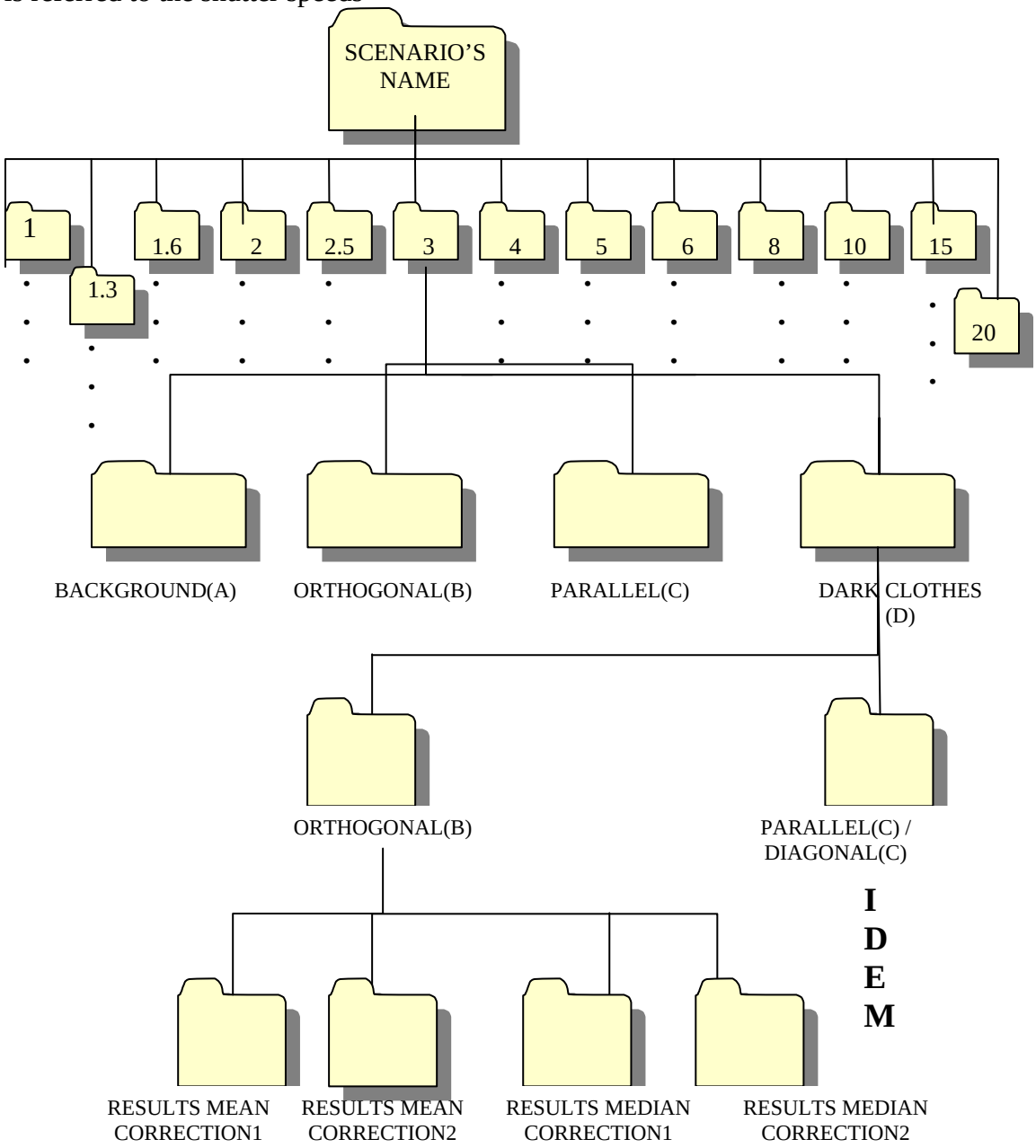
pre_str: string containing the characters previous to the number of the image. It also includes the number of zeros previous to the first integer different from zero.. For example, if the image it's called _R1E0232.png, the pre_str variable should be pre_str='_R1E0' considering the photo number equal to 232, so the variable first should be first=232

num_image: number of the image to be filtered.(omitting the zeros at the left of the first non zero value)

format: string containing he extension of the images. Do not include the character '.'
Example: format could take a value like:
format='png' or format='tif'

APPENDIX B

The structure of the folders containing the images is showed here, where the second row is referred to the shutter speeds



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-*"hmf"*
MATLAB M-file
Copyright (c) 2009, Damien Garcia
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http://www.mathworks.com/matlabcentral/fileexchange/25825-hybrid-median-filtering

-*"Video surveillance using Long Exposure Images"*
Andrea **Riva**, Marco **Uberti**